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PENNSYLVANIAN LIMESTONES OF NORTHEASTERN OHIO BELOW THE LOWER KITTANNING COAL.

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INTRODUCTION

In the Lower Coal measures of Pennsylvania and Ohio there occur certain beds of Limestone whose outcrop is known to be more or less continuous around the northern, the northwestern, and the western border of the Appalachian coal basin. This is true more particularly of those limestones occurring below the horizon of the Lower Kittanning coal. This coal with its companion, the famous Middle Kittanning coal, constitutes a band which, for extent, continuity, importance, and distinctness, is perhaps second to none in the belt of the Lower Coal measures. This band divides the Lower Coal Measure limestones into two groups—those below the Kittanning Coals and those above them.

The purpose of this paper is a discussion of the Limestones below these well known coals. Accordingly for definiteness and convenience of reference the line is drawn at the base of the Lower Kittanning coal.

REVIEW OF LITERATURE.

For our present knowledge of these limestones as they occur in the State of Pennsylvania, we are indebted chiefly to H. D. Rogers, H. Martyn Chance, I. C. White, and F. G. Clapp. Rogers in 1858 in his general section of the bituminous coal field of Pennsylvania (the section beginning in Mercer and ending in Greene County) gives only two limestones below the Lower Kittanning Coal. The lower one of 2 feet thickness he names the Mercer Limestone. [Geol. Penn. Vol. II, Part I, p. 476.] On the next page of the same report he gives another limestone—Mahoning Limestone—as forming the top of the Tionesta Group. On another page he states as follows:

"* * * * in the neighborhood of New Castle on the Beaver River, another limestone bed, the Mahoning Limestone, 2 feet thick, is interposed immediately under the Tionesta sandstone;" [Geol. Penn. Vol. II, Part I p. 489.]

Of the Ferriferous Limestone, which is the first one below the Lower Kittanning Coal, he states that it is so called because in many localities a valuable deposit of iron ore rests directly upon it. At New Castle he says this limestone rests upon the "Scrubgrass Coal-bed," the latter having a maximum thickness of 20 inches. (Geol. Penn. Vol. II, Part I, p. 491.]

In 1875 in his report on Beaver Valley, H. Martyn Chance states as follows:

"Both of the Mercer limestones were seldom seen in one locality one or the other generally being absent, and it is often difficult to tell to which of the two the one noted should be referred—the upper Mercer Limestone usually occurring at 90 to 115 feet beneath that stratum." (Ferriferous limestone.) [Sec. Geol. Sur. Pa. Vol. V. p. 189.]

In his report on Mercer County in 1878 under the head of *The Upper Mercer Limestone*, I. C. White writes as follows concerning that stratum:

"This is the 'Mahoning Limestone of Rogers' who recognized it on the Mahoning River, but not in Mercer County, where in fact it can only be seen at a few localities." [Sec. Geol. Sur. Pa., Rep. Prog. 1878 Q. Q. Q. Geol. Mercer County, p. 36.]

The same writer further says that in the southeast part of Shenango Township (the southwestern township of Mercer County and adjacent to Ohio), the *Mercer Lower Limestone* is here seen in two layers (a character which it often exhibits), the upper one 2 feet thick and the lower one 6 inches. There does not appear to be any separating material, not even the thinnest shale, but the layers appear to be in immediate contact, and both are richly fossiliferous; species of *Spirifer. Productus*, and *Crinoids* being especially numerous. [Geol. Sur. Q. Q. Q. p. 97.]

Discussing the ferriferous limestone in his report on Butler County, Chance makes this statement of it:

"In Ohio, except at Lowellville, on the Mahoning, where it exhibits its usual character, it is much thinner than in Pennsylvania, and, compared to its value in the latter state, is worth but little, either as a limestone or as an iron ore carrier. Its outcrop enters Ohio near the Mahoning river." [Geol. Sur. Pa. Report of Progress V, p. 142. 1878.]

In a bulletin prepared by F. G. Clapp and issued by the U. S. Geol. Sur. in 1904 on the "Limestones of Southwestern Pennsylvania," the ferriferous limestone is somewhat fully treated in an economic way. He renamed it the *Vanport Limestone* from typical outcrops at Vanport on the Ohio River in Beaver County,

Pennsylvania. [U. S. Geol. Sur. Bul. 249, p. 37.] This is clearly a better name than Ferriferous and it will doubtless prevail. He has mapped its outcrop in that state and shows it present up the Ohio, the Beaver, and the Mahoning Rivers, and that it is the thick limestone found in the hill tops at Bessemer, Hillsville and entering Ohio at Lowellville.

It is apparent from this brief review of Pennsylvania geology bearing on this lower group of limestone in that part of Pennsylvania adjacent to Ohio, that there are but three limestone so far observed. They are the Lower Mercer, Upper Mercer, and Vanport Limestones, the first two being named from outcrops near Mercer, Mercer County, Pennsylvania.

In Ohio we are indebted very largely to E. B. Andrews, J. S. Newberry, and Edward Orton for our present knowledge of the occurrence, the character, and the strata associated with the limestones considered in this paper. So often have they described and spoken of them in the Reports of the Ohio Geological Survey that indeed the names of these limestones—Lower Mercer, Upper Mercer, Putnam Hill, and Ferriferous, are quite familiar to every one at all conversant with Ohio geology. The first two and last of these names are of Pennsylvania origin as already noted. The third, or Putnam Hill, is a name of Ohio origin and was given by Andrews in 1869 to a conspicuous stratum of limestone typically exposed in the above hill at the foot of which nestles the city of Zanesville. [Ohio Geol. Sur. Rep. of Prog. 1869.] When Andrews named this stratum the other names did not exist in Ohio nomenclature, as it appears only one of the other three limestones was noticed. That stratum has since been considered the Lower Mercer and seen in the river bed at Zanesville. It does not appear, so far as the writer is aware, that these limestones observed at Zanesville were at first even suspected of being the same strata found beyond the Pennsylvania line. Later however these strata were traced northward through Muskingum, Coshocton, Tuscarawas, and Stark Counties, and the Putnam Hill found to be the principal limestone stratum but apparently disappearing from the section north eastward from central Stark County. The *Lower* or *Blue Limestone*, as it is usually called, was named the *Zoar Limestone* 1878 by Newberry from the typical exposures near Zoar in Tuscarawas County. [Ohio Geol. Sur. Vol. III, p. 60.] But this stratum was later regarded as identical with the Lower Mercer in Pennsylvania and the latter having priority the name Zoar is discontinued.

In his discussion of Coal No. 4 under the head of "The Carboniferous System of Ohio," Newberry in 1874 states that:

"Throughout the greater part of the belt of outcrop of the Lower Coal Measures in Ohio, at a distance varying from 20 to

90 feet above Coal No. 3 another coal, another limestone, and another ore bed are found. * * * * * * Where the interval between the limestones is considerable, two and sometimes three coal seams are found between them." (Ohio Geol. Sur. Vol. II, p. 139.]

The writer questions the interval of 20 feet between the Lower or Blue Limestone (which is probably the Lower Mercer) and the Putnam Hill. There are other limestones between these two which Newberry so far has not reckoned with and it seems quite probable that where an interval of much less than 90 feet occurs another stratum is met.

In his report on Stark County [Ohio Geol. Sur. Vol. III, pp. 151–176] Newberry nowhere mentions the presence of more than two limestones below the Lower Kittanning Coal. He regularly regards the upper one of the two given as the Putnam Hill, and the lower one, the Lower or Blue Limestone. There is evidently mistaken identification as will appear later in the detail study to follow.

One county remains to be considered which will complete a belt of territory extending from Muskingum County, Ohio, to southwestern Mercer County, Pennsylvania, in which belt the lower group of limestones occurs. The last link is Mahoning County. In his report on this county Newberry notes the presence of four limestones below the Lower Kittanning Coal as indicated in the "Section at Lowell" [Ohio Geol. Sur. Vol. III, opposite p. 804.] Near Youngstown three limestones are indicated as present [Ohio Geol. Sur. Vol. III, p. 803]. The upper one of these is certainly a new stratum and not in the "Section at Lowell" as will be shown later. On Indian Creek in Canfield Township he notes the presence of two limestones and designates the associated coals as "No. 3 and 3a," which would indicate that he regarded the lower limestone as the Lower or Blue Limestone. This identification will be considered later.

In his report on Coshocton County, Read notes a limestone between the "Blue" or "Zoar," and the "Gray" or "Putnam Hill," and near the former. [Ohio Geol. Sur. Vol. III, p. 567.] Andrews appears to have observed another limestone near the Zoar or Lower Mercer in northern Muskingum County. He also notes a thin limestone above the Putnam Hill at Zanesville. [Ohio Geol. Sur. Vol. III, p. 823.] Orton also notes a limestone 30 to 40 feet above the Zoar in Vinton and Hocking counties, which he names the "Gore Limestone" in 1878, apparently from a village in north-eastern Hocking County. [Ohio Geol. Sur. Vol. III, p. 898.] Thus in 1878 a limestone occuring between the Lower Mercer and the Putnam Hill was recognized in rather widely separated places.

In 1884 Dr. Orton in a discussion of the "Stratigraphical Order" gives the fullest account of the Lower Coal Measure Limestones yet to appear. He here correlates the Gore Limestone with the Upper Mercer of Pennsylvania and regards the limestone found between the Lower Mercer and Putnam Hill in the different counties as identical with the Upper Mercer. He states that:

"It everywhere lacks the remarkable steadiness and continuity of the Lower Mercer, but in all other respects it is almost the exact counterpart of that well-marked stratum. It has, in the main, the same chemical composition, the same color, and other physical properties, and also the same fossils. In many instances the limestones can be distinguished only by their stratigraphical order." [Ohio Geol. Sur. Vol. V, p. 15.]

In discussing the Ferriferous Limestone, Dr. Orton says of it,

"* * * * there are still unsettled questions as to its westward extension through a number of counties."

"From the eastern side of Mahoning County, to the center of Perry County, the Ferriferous Limestone is either feebly developed and obscure or is altogether wanting. But in this very interval where the Ferriferous Limestone has grown weak and uncertain, another limestone of the same general character is found, which completely bridges the chasm and by means of which we are able to maintain the unity of the series unbroken. This is the Gray limestone of Newberry and the original Putnam Hill of Andrews."

"* * * * The Putnam Hill limestone underlies the Ferriferous by 15 to 50 feet. The usual interval may be counted 30 feet.

"* * * * The Putnam Hill limestone is from 25 to 50 feet above the Upper Mercer Limestone * * * *." [Ohio Geol. Sur. Vol. V, pp. 19–21.]

In a report in 1906 dealing with the limestones of Ohio, Edward Orton, Jr., and S. V. Peppel review these Coal Measure Limestones and make the following statement regarding the Putnam Hill:

"It is very close, stratigraphically, to the Ferriferous Limestone, a very important bed. The area occupied by the two does not overlap, so far as the knowlegde of the writers extends. At the point where the Ferriferous is present, the Putnam Hill is not likely to be found, and vice versa. Both stones lie close below the Lower Kittanning or No. 5 coal, but they are probably stratigraphically distinct." [Ohio Geol. Sur. Vol. IX, Bull. 4, p. 173.]

Of the Ferriferous Limestone, the same writers state that:

"In stratigraphical position, the Ferriferous belongs a short distance above the Putnam Hill Limestone and from twenty to forty feet below the Lower Kittanning coal. This places it near the bottom of the Allegheny formation.

"* * * * Toward the southwest (from Lowellville) the formation becomes more and more sparing in its exposures, and thinner, until in southwestern Stark County and northeastern Tuscarawas County it disappears, and the Putnam Hill Limestone comes in on nearly the same horizon, but stratigraphically distinct." [Ohio Geol. Sur. Vol. IX, Bull. 4, p. 174.]

From this brief review of the literature on these limestones it is quite apparent that three limestones are recognized in Western Pennsylvania below the Lower Kittanning Coal, and in Ohio four are recognized below the same horizon. In the former state the Lower Mercer and Vanport are the more important stratigraphical horizons; in the latter state the Lower Mercer and the Putnam Hill have that distinction. It is also apparent that uncertainty characterizes the present knowledge of the presence and character of the westward extension of the Vanport limestone from eastern Mahoning County, and likewise the eastward extension of the Putnam Hill from Central Stark County. The Lower Mercer is regarded as the unfailing limestone from Mercer County, Pennsylvania, to Zanesville, and as the lowest and earliest limestone in the Lower Coal Measures. The Upper Mercer is conceded to be present in many places, but by no means so regularly present as the Lower Mercer.

SURFACE, STREAMS, AND ELEVATIONS.

From central and southern Stark County southwestward, it would appear from the Ohio Reports that these limestones are fairly well known and the same can be said of them on the eastern line of the state. But from central Stark County to the Pennsylvania line they are not well known. Consequently a somewhat careful examination has been made of this territory covering an extent of about fifty miles. Of the region examined all but a little in southern Stark County is deeply drift covered, and only now and then can the strata be seen to emerge from the drift mantle save along streams and even here long intervals often occur between meager outcrops.

From west to east the following streams and tributaries have been examined for outcrops of the above limestones: Nimishillen Creek, Mahoning River, Island Creek, Little Mill Creek, Turkey Broth, Meander Creek, McMahon Run, Diehl Creek, Mill Creek, Neff Run, Indian Creek, Yellow Creek, Burgess Run, and Furnace Run, all of which are shown on the accompanying map of Stark and Mahoning Counties.

Elevation will be seen to be an exceedingly important factor in obtaining the results of this investigation and it is constantly employed in determinations. The elevations given were obtained by level from elevations indicated in the field by the

United States Geological Survey, from railroad elevations, and in a few cases from topographical maps. In every case the elevation given below will be understood to mean the *elevation of the top of the stratum named*, and intervals between strata will be understood to mean *between their tops* unless otherwise explained.

Other strata associated with the limestones receive attention only in so far as they add interest to the setting and identity of the limestones in different places, or when well-known horizons are exhibited and call for brief recognition.

DESCRIPTION OF SECTIONS.

Nimishillen Valley.

Howenstein. In the valley of the Nimishillen about six miles south of Canton and about four miles north from the county line good outcrops of limestones are found near the village of Howenstein. A rather long section is afforded here since the valley is narrow and deep and the hills rather high. Almost every foot of the strata may be seen from the Lower Mercer Limestone in the bed of the stream up to thirty feet or more above the Middle Kittanning Coal. At Howenstein a limestone is found in the creek bed but cannot be seen well here. At Mr. John Shew's Mill a half mile below the village the limestone is still found in the stream bed.

A wall under the mill is constructed of this stratum lifted from the stream bed and the thickness is seen to be 10 to 12 inches. It is reported by Mr. Shew to be one foot or a little over and lifts in two layers. It is underlain by a thin coal and is dark gray in color weathering to a yellowish gray. Segments of crinoid stems and brachiopods constitute the fossils seen. The limestone can be seen some distance below the mill in the creek bed.

Above the railroad on the west side of the stream occurs a second limestone which is undoubtedly the Upper Mercer as will appear from sections to follow. This point is about 300 yards below the mill, and the interval from top to top where measured is 28 feet which is greater than the usual interval between these limestones. The interval is usually 20 to 25 feet. At this outcrop the Upper Mercer is 14 inches thick and in one layer. In other characters it is practically like the lower limestone. Four hundred yards above the mill and on the west side of the railroad this stratum is seen to be 21 inches thick and resting upon 18 inches of coal. It is also seen to rise and fall, or undulate and is certainly considerably less than 28 feet above the lower limestone, probably less than 20 feet in places. It can be seen at a number of points along the railroad up to Howenstein where it is seen at several points on the east side of the creek in the bank above

the dugway. At the south end of the dugway, or highway cut, it appears at the same level as where last seen on the west side near the railroad switch below Howenstein a few hundred yards.

It may be noted in passing that the Upper Mercer coal thickens here to about 3 feet and a mine has been opened in it a quarter of a mile below Howenstein.

The overlying limestone is also removed. This is the only mine met with in the territory covered opened in this coal; it nowhere else was found reaching this thickness.

Near the north end of the highway cut the Upper Mercer limestone is well exposed beside the roadway. It occurs in two layers, the lower layer being very tough, bluish gray and 23 inches thick. The upper layer is brownish, coarser grained, contains considerable iron ore, and is 10 inches thick. The two layers thicken and thin at the expense of each other. No coal is found under it.

At this outcrop a ravine trenches the hillside, and in this ravine two or three rods above the roadway another stratum of limestone is found at 22 feet 7 inches above the Upper Mercer limestone, and 15 inches thick. It is blue-black, very tough, and in one layer. It can be seen all along the bank above the roadway, but concretionary rather than as a continuous stratum. Coaly shale and fire clay underlie it. Northeast of the creek bridge at Howenstein about 200 yards and beside the hill road it may be seen in the run bed for several rods where it occurs in a definite bed showing decided undulation. This stratum is not the Putnam Hill limestone as might be thought. It is too near the Upper Mercer, and too far below the Lower Kittaning Coal, besides the Putnam Hill is present in the section at its proper horizon. It is clearly a new element not before recognized. Again, it is not merely a local development but is found nearly to the state-line as will appear in descriptions to follow.

Having to deal with it repeatedly the writer names it the *Howenstein limestone*. At the south end of the highway cut and near the bridge the Howenstein limestone lies at 991 feet above sea, and 21 feet above rail at Howenstein depot. From this elevation the Upper Mercer is seen to lie at about 967 above, and the Lower Mercer at about 939.

In the hill-side ravine spoken of above and sixty feet above the Howenstein limestone a fourth limestone occurs at 1051 feet above sea. This is undoubtedly the Putnam Hill which is here 2 feet, 8 inches thick and resting upon a bed of coal. Being only partially exposed the thickness was not obtained. Two miles up the Nimishillen this coal lies in two benches and is 4 feet thick capped by the same limestone. As seen in the above ravine this limestone is rather a dark gray, weathering to a gray or a yellow-gray. It is very tough and lies in one layer. Crinoid

stems and brachiopods were the only fossils noted. In general appearance it is not enough unlike the Mercer limestones to distinguish between them readily. But the Howenstein can be easily distinguished from either of the others by its much darker color.

A fourth of a mile east of this outcrop and on the hill-road a little above the point where it emerges from the woods, the horizon of the Putnam Hill is marked in the roadway by fireclay and coal blossom which lies 64 feet above the Howenstein limestone as seen below beside the hill road. A few hundred yards further to the east and to the right of the road and on the farm of Mr. John Shertzer the Lower Kittanning coal is well exposed in a clay pit at 1125 feet above sea.

It is three feet thick and is underlain by about 20 feet of fireclay. The top of this coal lies about 73 feet above the Putnam Hill limestone. 39 feet below the top of this coal a bed of fireclay occurs which marks the horizon of the Vanport limestone at 1086 feet above the sea. The limestone does not appear at this point but about four hundred yards north of the Shertzer barn in a ravine in the edge of the woods the limestone was found and at 39 feet below the top of the above coal. The limestone as found here does not exceed 8 inches thickness, is of a dark gray color, weathers to a rusty-brown, and is sparingly fossiliferous.

It may be noted here that the Middle Kittanning coal is 3 feet, to 3 feet 8 inches thick and lies at 1160 above sea.

North Industry. At the head of the gorge of the Nimishillen and about 3½ miles below Canton is the village of North Industry. Outcrops of limestone are numerous in this vicinity and all five are again found with ease especially the four lower ones. The top of the rail at the depot lies at 998 feet above sea, and directly above the station in the old shale quarry the Putnam Hill may be seen at 59 feet above rail or 1057 feet above sea. Here as elsewhere in the valley of the Nimishillen it is an unmistakable horizon. It is 4 feet thick in places and possesses practically the same characters as in the preceding section. 2 inches of shale separate it from the 18 inch coal underlying it. The Howenstein limestone is due at about the level of the depot but is not seen there. A short distance below the station along the tracks it is imperfectly exposed. Opposite the station and near water level in the creek, occurs the lowest limestone visible in this immediate locality. It lies 78 feet below the Putnam Hill at the highest point observed, or at 979 above sea. It will exceed the interval of 78 feet, however, by several feet as it is observed to sink beneath the stream. This is undoubtedly the Upper Mercer or the second limestone noted at *Howenstein*. As seen here it is 21 inches thick, in three layers and much ironstained, the upper layer of 3 inches thickness being heavily charged with iron ore. Sandy shale underlies it.

A typical section for this region may be found about ¾ of a mile below. Beside the residence of Amanda Stallman a deep ravine exposes the four lower limestones. Well up the hillside the Putnam Hill is found with a thickness of 3½ feet resting upon coal partially exposed. Forty-four feet below its top occurs the Howenstein 1 foot, 9 inches thick tougher and much bluer than the Putnam Hill. Twenty-one feet, 6 inches below the top of the Howenstein lies the Upper Mercer in the run bed beside the Stallman residence. It appears to be double here. The upper half is 2 feet, 9 inches in thickness, lies 2 feet above the lower half, is bluish in color, quite tough and in several layers. The character of the two feet between the halves was not seen. The lower half is two feet eight inches thick and in three layers. The bottom of the lower half lies 6 feet above water in the Nimishillen. About 4 feet below water surface lies the Lower Mercer in the creek bed. It is clear therefore that the two divisions just given is not a close approach of the two Mercer limestones but a split of one of them. Nowhere else was this character found, but it is suggested in the expression of the two layers as noted at Howenstein. It is possible that the limestone seen near creek level opposite the North Industry depot is this upper half of the Upper Mercer. The Lower Mercer in the creek bed is said to be about 1 foot thick and lies 17½ feet below the top of the Upper Mercer. A little below, this limestone is seen at the ripple near the highway bridge.

A short distance below the Stallman ravine and on the opposite side a deep ravine joins the gorge at the mouth of which is the tipple of The Nimishillen Coal Company. The mine is a few hundred yards up the ravine and is opened in the coal beneath the Putnam Hill limestone. The coal lies in two benches two feet each with a conspicuous 3 inch shale parting as seen at the lower opening. The limestone is massive, tough, and having a bluish tint where freshly quarried. Two layers are presented here, the lower one 1 foot, 2 inches, and the upper one 2 feet, 8 inches in thickness. Crinoid stems and brachiopods comprise the fossils observed. The company has been quarrying the limestone recently and crushing it for macadamizing. At the upper opening the limestone and coal present the same characters except the lower bench of coal has thickened to two feet nine inches.

The section begun in the Stallman ravine may be completed here. At the point where the Putnam Hill becomes the ravine floor and on the left hand the steep slope presents every foot of the strata up to a point considerably above the horizon of the Vanport limestone. No definite bed distinctly limestone is found here. But at 37 feet above the Putnam Hill irregular concretion-

ary masses of 3 to 8 inches thickness and much iron stained respond promptly to acid. These are imbedded in the dark gray sandy shale and would never be noticed were one not looking sharply for the vestiges of limestone.

Canton. From North Industry up the valley the Putnam Hill is exposed at different places, but the next good exposure occurs at the Imperial Brick Plant in southwest Canton where the shale above and the fireclay beneath this limestone are used in brickmaking. Here the Putnam Hill is 2 feet, 9 inches thick and underlain by 18 inches of coal.

As nearly as can be determined from a topographic map its elevation is 1075 feet above sea. The hill is high enough to carry the Vanport but it was not seen, arenaceous shale occupying its horizon.

The brick plant is located on the roadway leading to Navarre and just above the bridge crossing a small creek near the brick plant the Howenstein limestone is exposed in the creek bank 5 feet above the stream level. It lies 50 feet below the top of the Putnam Hill or at 1025, is bluer than the upper limestone, and is 1 foot thick. One to four inches of yellow clay and 4 inches of coal beneath the clay directly underlie the limestone.

In his report on Stark County Dr. Newberry constantly refers to the limestone below the Putnam Hill as the "lower limestone" and in reference to certain borings in the vicinity of Canton states that they were begun at about the horizon of the "lower limestone" which he reports is visible in places. These borings appear to have been in the vicinity of the above outcrops of limestone, and it seems quite certain that his "lower limestone" is the Howenstein. In the well section given it is 1 foot, 2 inches thick. [Ohio Geol. Sur. Vol. III, p. 159.] This is quite in accord with the Howenstein as seen near the brick plant. Another stratum of interest, however, appears in the above well section. Twenty-two feet below the top of the above 14 inch limestone is recorded a "Hard Blue Rock" 2 feet and 1 inch thick. The driller does not seem to have known just what to call it, and Dr. Newberry does not seem to have suspected it of being another limestone, which it certainly is. At Howenstein the same interval is 22 feet 7 inches, in the Stallman ravine 21 feet, 6 inches. From these facts the identity of these limestones as found in southwest Canton appears to be unquestionable. The "lower limestone" of Newberry, therefore, is the Howenstein, the "Hard Blue Rock" is the Upper Mercer, and the Lower Mercer absent being replaced by shale and sandstone.

In northwest Canton in the sides of a ravine which enters the West Lawn Cemetery from the west, limestone occurs at about 1090 feet above sea, as nearly as could be determined

from topographic map. It was formerly quarried and burned beside the roadway on the west side of the Cemetery. The owner of the land reports the limestone as 4 feet thick and underlaid by about 2 feet of coal. This stratum is clearly the Putnam Hill limestone.

Middle Branch. In the vicinity of Middle Branch a village about 7 miles north of Canton several outcrops of limestone occur. In fact almost anywhere at the proper horizon where the native strata occur limestone is present. It is often absent but this is due to preglacial erosion and drift now occupies its position in such places. The most extensive exposure of this conspicuous stratum occurs at the quarry of the Diamond Cement Works about a mile north of Middle Branch. This point is nearly 8 miles from the outcrop in northwest Canton, but various outcrops from Canton northward show this heavy stratum with its underlying coal to be the Putnam Hill limestone. The 11-inch coal as seen in the quarry is heavily charged with sulphur which is typical of it south of Canton. Furthermore a limestone is found above the quarry stratum near the quarry, and the elevation of the limestones here indicates a gradual rise which is quite in harmony with facts found from Howenstein to Canton. It appears quite clear from all the data given that the limestones here to be described are the Putnam Hill and the Vanport. At this quarry acres of the Putnam Hill have been removed for the manufacture of cement and the best opportunity for studying this stratum found anywhere is presented here. It attains a greater thickness here than it is known to have in any other outcrop of its whole extent. The stratum as seen at the present time in the quarry is mostly overlain by drift and shows much scoring by the ice where the top is exposed especially on the north side of the quarry. In the center of the quarry a large block of the limestone has been left stand temporarily in order that the overlying shale may be used in the manufacture of cement. Practically everywhere else the ice seems to have swept the limestone bare but here in the center 16½ feet of brown arenceous shale caps the stratum. The quarry is being extended northward toward the hill and the same shale will doubtless be encountered in a few years. A very striking feature of the limestone is the pronounced undulation found. This is a character, however, common to all the limestones but no other outcrop affords so good an opportunity of seeing it in the Putnam Hill. It is quite evident that such undulation will affect the measurements of sections, especially where the wave crest of one limestone occurs above the trough of another, thus making the strata appear farther apart than they really are, or again if the section be measured where a crest of the lower, and a trough of the upper occur they will

appear to be closer than they really are. Ordinarily it is not possible in a limited outcrop to determine whether undulation exists or not. Therefore in sections where limestones are shown to be unusually close together or unusually far apart it is only fair to suppose that undulation is probably the cause provided the difference be not over 15 to 17 feet as no undulation observed exceeds that measurement.

In the above quarry the rise and fall was not observed to exceed 6 or 7 feet and no definite order was discovered as the rising and falling occurs, no matter in what direction the observation be made. The limestone merely conforms to the topography of the sea bottom on which it was laid as a mud without becoming thicker in the depressions and thinner on the elevations of that bottom. Had the mud or ooze been considerably greater in specific gravity than the water in which it was laid it would doubtless have glided slowly into the depressions where the greater slopes occur and thus cause the upper and lower surfaces to be less parallel than we find them.

As nearly as could be determined from a topographic map the top of the Vanport lies at 1180 above sea as seen in the hill-top directly north of the quarry and the Putnam Hill lies 37 feet below, or 1143 above sea as measured in the northeast corner of the quarry.

The following section measured near the center of the quarry represents the character of this limestone fairly accurately.

		Feet	Inches
	Brown arenaceous shale	16	6
8.	Limestone layer	1	7
7.	Parting, calcareous shale	0	2
6.	Limestone layer	1	4
5.	Limestone layer	0	7
4.	Limestone layer	1	11
3.	Limestone layer	1	8
2.	Parting, thin shale	0	0
1.	Limestone layer	0	11
	Coal	0	11

No. 8, or the top layer of limestone, is perhaps the most distinct layer in the quarry and is readily recognized in any part of the quarry where it has not been cut away by the ice. The shale parting beneath gives it the well marked separation from the next layer. On weathering it tends to split up into numerous thin layers and does not appear to be as pure a lime as the lower layers.

No. 7 is a conspicuous parting of bluish calcareous shale of 2 inches thickness. It is the most sharply defined and constant plane of separation in the quarry.

No. 6 is dark gray in color, is not so compact as 4 and 5 below it, and has more jointing planes than these layers. It rests immediately upon No. 5 from which it is separated by an uneven bedding plane and has a thickness of 16 inches.

Nos. 5 and 4 having a thickness of 7 inches and 23 inches respectively, are brown-gray in color, quite compact, weather less easily than the upper layers, and are said to be the best stone in the quarry. These layers are separated by a peculiar wavy bedding plane the elevations of which measure 1 to 1½ inches and 3 to 5 inches between as seen on the rock face.

No. 3 measures 20 inches, is of a gray color slightly darker than the layer below it and also purer lime than that layer but not so good as those next above it. It is more compact than the lower layer.

No. 2 is a thin calcareous shale parting of negligible thickness and of the color of the stone.

No. 1 has a thickness of 11 inches, is gray in color and is said to weather to a shale condition after a few months exposure. It is not as tough as the middle layers and rests upon the coal.

In the south wall of the quarry the limestone presents five layers below the conspicuous shale parting but of nearer equal thickness than shown in the above section.

The outcrop of the Vanport noted above occurs in the hill-top just above the township road in a private roadway about 30 yards north of Mr. Adam Cocklin's barn and about 200 yards north of the quarry. This stratum is poorly exposed and as nearly as could be determined it is 6 feet, 5 inches thick, caps the hill and is thinly covered with drift. It may be seen again in the township road ¼ mile east of this outcrop and near the residence of Mr. Adam Wise, where it again caps the hill. Mr. Wise reports the presence of a thin coal beneath it.

Little more can be said of this limestone from the poor outcrops afforded. It is bluish gray in color and less fossiliferous than its companion so far as could be seen.

It probably occurs in all the surrounding hills whose strata are high enough to carry it but with its outcrop obscured by drift.

Its occurrence here in rather heavy body and above the Putnam Hill, which at this point exhibits the greatest development it is known to possess, is somewhat in contrast with the supposition that the two limestones do not overlap and that as the one appears the other disappears.

One mile south of the Middle Branch on the farm of William Worstler a quarry was operated on a small scale for many years and the stone burned for lime with the underlying coal. The following section indicates the character of the stratum in this quarry.

	Drift	Feet	Inches
9.	Calcareous shale	1	0
8.	Clay parting	0	1½
7.	Limestone layer	0	2
6.	Limestone layer	0	2
5.	Limestone layer	0	3
4.	Limestone layer	0	4½
3.	Limestone layer, massive	2	6
2.	Limestone layer	0	11
1.	Limestone layer, thickness not seen but probably about	1	0

The calcareous shale at the top lies in numerous definite layers and contains considerable alumina. It lifts readily in thin layers at the thin clayey partings. The clay parting between this shale and the limestone proper leads one to identify it at once with the 2 inch parting in the quarry at the cement works. The worthless shale here above the clay parting becomes an impure limestone at the cement works. The limestone has a light blue color and the coal beneath is said to be 14 inches thick. The Limestone lies at about 1120 feet above sea and is undoubtedly the Putnam Hill.

Mr. D. L. Worstler in 1907 opened a quarry to burn lime on the farm of B. F. Werner 1 mile southwest of Middle Branch and 1 mile northwest from the Worstler quarry. The elevation is about 1130 above sea. No shale layer or clay parting occurs here as drift lies directly upon firm rock. The following section indicates the nature of the stratum in this quarry.

	Drift	Feet	Inches
5.	Limestone, bluish gray	2	8
4.	Limestone, bluish gray	1	4
3.	Limsetone, black	1	2
2.	Shale, bluish black	0	3
1.	Coal	2	4

The upper part of the stratum of limestone has doubtless been eroded as the top layer shows abrasion. No. 4 is more compact than No. 5 which is in accord with the middle layers at the Cement Plant.

No. 3 is black and porous, and not so compact as No. 4. The pores are filled with oil which soon greases a freshly broken face and yields the characteristic odor. The coal is ample for burning the lime and runs from 24 to 28 inches in thickness. At a farm house about 350 yards west of this pit a limestone was penetrated in a well at about 35 or 40 feet above the quarry stone. These limestones are clearly those at the Cement Works.

Dip of the Strata in the Nimishillen Valley.

It readily appears from the elevations of the limestones at the various outcrops that there is a dip of the strata toward the south. Placing the elevations together of any one stratum from

south to north a gradual rise is observed. The Putnam Hill affords the best example being found at more points than any of the others.

It lies at Howenstein at 1051, North Industry 1057, southwest Canton 1075, northwest Canton 1090, Worstler quarry 1120, Werner quarry 1130, and at the Cement Plant at 1143. There is a fall therefore of 92 feet in this stratum from the latter place to Howenstein a distance of about 13 miles, or 7 feet per mile. The same is true of the Vanport which at Howenstein lies at 1086, at Cement Plant at 1180, and a fall of 94 feet or of 7 feet per mile.

This is not the direction of the greatest dip, however, as will be seen later.

EASTERN STARK COUNTY.

Alliance. But few limestone outcrops have been found in the eastern part of the county. The region is deeply drift covered and the strata are concealed for the most part. Two outcrops and two well sections afford the only information at hand on these limestones in that part of the county, and of these the well sections and one outcrop occur at Alliance. This city lies 10 miles east of the Cement Works mentioned above and the strata lie considerably lower at the former place than the latter. The Middle Kittanning coal lies at 1132 feet above sea in the coal shaft near the city Stand Pipe. In a test well drilled by the city on West State Street it lies at 1040, and at the Ely shaft ½ mile southwest of the Transue-Williams Machine Shops it lies at 1137 above sea. The Lower Kittanning coal was formerly mined near the above shops at 1100 above sea as nearly as could be determined. A half mile north of the above shops and the same distance west of the Alliance Cemetery a limestone outcrops on the Ellett farm at 1081 above sea. This is clearly the Vanport but it is closer to the Lower Kittanning coal than at Howenstein. The limestone is exposed in a pit near the Ellett barn and measures 5 feet in thickness. No coal but 4 feet of fireclay immediately underlies this stratum, and is overlain by 2 to 3 feet of drift. It differs from any other outcrop of limestone found in that it is composed of numerous irregular layers ranging from a fraction of an inch to 4 or 5 inches in thickness. It lifts in broad pieces of a very irregular form, sometimes wedge shaped. The stone is very impure, many of the slabs being a sandstone rather than a limestone and the parting between the slabs is clay or sandy shale. Some layers contain fairly pure limestone of a light blue color and quite compact. The stratum presents an alternation of irregular bands of light blue and brown, the shale and sandstone portions having the latter color. The stratum at this point seems to have been deposited in shallow water which was sometimes quiet and clear and sometimes flowing and muddy thus

giving the alternation of material noted. The stratum is quite fossiliferous containing brachipods, lamellibranchs, gastropods, and crinoid stems.

The next section to be considered is the test well drilled by the City just off West State.

The elevation of the well head is 1244 feet above the sea, and the Middle Kittanning coal was penetrated at 1140 and 2 feet thick. The Lower Kittanning is wanting and a 15-foot limestone is reported at its horizon the top of which lies at 1103 feet above sea. No limestone is known to the writer to occur at this horizon, and nothing further is known of the presence of such stratum than the bare name and thickness indicated in the City Engineer's section prepared from the data given by the driller. The driller's interpretation of this part of the section may be questioned with reason. It is much more likely a shale with possibly some calcareous matter in it. This horizon has been penetrated in many places in the lower part of the city as well as other drillings in the upper part of town not far from this well, and limestone is not mentioned at this horizon.

Where the level of the Vanport occurs white shale is indicated as present. At 1032 an 8 foot stratum was struck which the driller designated "Bastard Limestone." This is certainly the Putnam Hill Limestone with an interval of 49 feet between its top and that of the Vanport. The same interval at the Cement Plant is 37 feet and the difference is not too great to be accounted for by undulation, besides the Vanport is seen to lie unusually close to the Lower Kittanning coal. The interval at Howenstein between the top of the Putnam Hill limestone and that of the Middle Kittanning coal is 109 feet. In this well section it is 108 feet. It would seem that the identity of this limestone is evident. The thickness given is in harmony with that at the Cement Plant.

At 1008 feet above sea another limestone is recorded with a thickness of 9 feet. This is doubtless the Howenstein but with an indicated thickness greater than found in any outcrop. The interval is only about half that along the Nimishillen and apparently too great to be accounted for by undulation. It would seem to require a thinning of intervening strata.

In this well the horizon of the Mercer limestones is occupied by shale but in the next well to be noted they are both present, and for the sake of clearness, they are noted in this connection. The Upper Mercer lies at 966 above sea and reported to be 8 feet thick. This gives an interval of 42 feet between it and the Howenstein which is about as much greater than this same interval at Howenstein, as the interval here between the Putnam Hill and the Howenstein limestone is smaller than that same interval near

that village. At Howenstein the interval between the Putnam Hill and the Upper Mercer is 84 feet, at Alliance 66 feet and considering the fact that the Lower Mercer is present at its usual interval it would seem that this difference of 22 feet could hardly be regarded as due to undulation. It is possible however that both the Mercer limestones were penetrated on a crest which would account in part for the difference. Otherwise a thinning of intermediate strata is the explanation.

The Lower Mercer lies at 945 or 21 feet below the top of the Upper Mercer which is about its usual interval. It is recorded as 3 feet thick which accords quite well with its known thickness.

In the first well at an elevation of 884 feet above sea another limestone was penetrated having a thickness of 5 feet. This is clearly a stranger as it lies 61 feet below the Lower Mercer.

The second test well was drilled beside the city pumping station with the well head at 1044 above sea. The second well is nearly 2 miles north and ½ mile east of the first. This distance would seem at first to forbid the combination of measurements given above. But certain facts indicate that it may be done with a fair degree of certainty. (1) The Middle Kittanning coal in the Ely shaft lies at 1137 and in the first well at 1140. These points are nearly 1 mile apart and the shaft a little west of north. This would indicate that the plane of this coal in this direction is nearly level. Mr. Ely states that the coal rises a few feet from the shaft which further indicates horizontality. (2) In the second test well a 5-foot limestone was penetrated at 882 feet above sea, in the first well at 884 above. (3) Near Myers Station on the Lake Erie, Alliance and Wheeling Railroad, 11 miles south of the Ely Mine the Middle Kittanning coal lies at 1130 above sea, or a fall of 7 feet in 11 miles. From the first test well the fall is 10 feet in 10 miles.

These data indicate that the strata at Alliance lie very nearly on a level from north to south. Therefore the strata may be counted practically level so far as these two wells are concerned, and the combination made as given above.

Little more need be said of the second well. Sixty-eight feet of the top is drift and the bed rock is reached at 976 above sea, which is below the horizon of the Howenstein. The only other limestones to be expected are the Upper and Lower Mercer and these are present as noted above. The stranger is present also at 63 below the Lower Mercer as already stated. Sixty feet below the top of this limestone lies a 2 foot coal which is apparently the Sharon coal. It lies 37 feet lower than coal No. 1 in the Mullin Mine at Deerfield which would indicate that it is the same coal. This limestone will be considered further in another connection.

The second limestone outcrop in the eastern part of the county to be discussed occurs on the farm of Samuel Carr at a point

about 4 miles west of the exposure on the Ellet farm. This stratum is quarried and burned on a small scale by the Clapsaddle Brothers and is used by the Alliance City Disposal Plant which uses about 200 bushels of lime per week.

The quarry is opened beside a small run and nearly at run level. This stratum is 5 feet thick and lies at 1117 above sea. In places it is said to exceed this measurement and rests upon coal 5 to 18 inches in thickness. It is composed of several layers, is bluish gray in color and fairly fossiliferous. The upper third is somewhat lighter in color than the lower part, and the quarrymen state that this limestone produces a purer lime than the stone at Middle Branch.

No other limestone was found and the identity of this stratum would be difficult, if not impossible, to determine from what can be seen of it and the associated strata. In the absence of other data its identity may possibly be established in another way. Since the elevation of the Vanport at the Cement Plant is 1180, and 1081 on the Ellett farm, the strata are seen to dip toward Alliance 10 feet per mile. If this limestone in question be the Vanport then at 4 miles to the west of the Ellett farm it should lie at 1121 which is within 4 feet of the elevation actually found. If it be the Putnam Hill limestone whose elevation at the Cement Plant is 1143 and 1032 at Alliance having therefore, a dip of 11 feet per mile, at the Carr farm it should lie at 1076 which is 41 feet lower than the limestone is found to be. This would seem to identify it as certainly the Vanport. But the presence of a low fold between Alliance and Middle Branch would alter this conclusion. No evidence, however, of such a condition is known to the writer, hence he regards this as an outcrop of the Vanport.

Another section in the northeastern corner of the county is of interest in this connection. About 3 miles northeast of the Carr farm and on the diagonal road leading from Limaville to Marlboro at a point 2¼ miles southwest of Limaville is the shaft mine of Mr. Fred Lare. The elevation of the top of the shaft is about 1155 feet above sea.

Mr. Lare gives the following section:

4. Drift	42	feet.
3. White sandstone, hard and shaly	3	"
2. Shale, dark	15	"
1. Coal, bone parting near middle	4	"

This 4 foot coal which is said to be a good steam and heating coal lies at about 1095 above sea which is at once seen to be below the Carr limestone and with no trace of limestone in the shaft. The thickness and the parting in the middle strongly suggest the coal beneath the Putnam Hill limestone. This shaft, the Carr farm, and Howenstein are in line. The Vanport at Howenstein lies at 1086, on the Carr farm at 1117 and the two points are 16

miles apart. This shows a rise of 2 feet per mile, and if the Vanport were present in the shaft it would lie at about 1123 above sea. This puts the coal 28 feet below the Vanport horizon which is reasonably near the proper horizon for the coal beneath the Putnam Hill limestone. Furthermore no other coal between the Sharon and the Lower Kittanning is known to reach any such thickness or present a conspicuous parting in the middle. It may be confidently concluded that this is the coal of the Putnam Hill limestone with that stratum absent.

Deer Creek at Limaville lies at about 1040 above sea, low enough to expose one or two of the lower limestones but none were seen.

Dip of Strata in Eastern Stark County.

With the several elevations now at hand *dip* of the strata in the eastern half of Stark County may be still further noted. With the Vanport at 1086 at Howenstein, 1081 at Alliance, and 1180 at the Diamond Cement Plant, it appears that the strata lie almost horizontally from Howenstein to Alliance, but if the sum of the elevations of the five limestones at the two places be compared they will be seen to be 5034 and 5032 respectively which indicates almost a perfect level. A line drawn through the Cement Plant outcrop at right angles to the Alliance–Howenstein line gives the direction of maximum dip for this area. It is south about 45 degrees east and 14 feet per mile.

From the Cement Plant to the Ellett farm it is 10 miles with a fall of 99 feet and a little north of east. The Middle Kittanning coal at Howenstein lies at 1160; 12 miles slightly north of east near Myers Station it lies at 1130, or 30 feet fall. It is at once seen that these two lines of fall do not lie in the same plane, therefore a disturbance in the dip. In the absence of more data it can not be definitely stated what the cause is, but the writer offers the following tentative explanation. Entering Stark County from the southwest a low fold extends in a northeasterly direction the crest of which lies a little west of Canton and perhaps not far from Middle Branch. Parallel to this fold another is thought to extend through western Columbiana and central Mahoning counties. It is thought that Alliance lies near the bottom of the intervening trough or on the syncline, that Howenstein is situated west of the syncline and Myers Station east of it. The horizontal position of the strata at Alliance and the fact that there is less than 1 foot fall to the mile toward the south from that city inclines the writer to think that in going toward Myers Station the west slope of the anticline is gradually ascended and thus accounts for the slight dip in that direction. The line from Middle Branch to Howenstein is nearly parallel to the direction given above and it will be remembered that the dip here is 7

feet per mile and this is just what would be observed in traversing the slopes of anticlines in this way. Furthermore, an oil field is located 4 to 8 miles southeast of Alliance which strongly indicates the presence of an anticline. Other evidence of a fold to the east of Alliance will occur later.

SOUTHWESTERN MAHONING COUNTY.

Bests Station. This point is 4½ miles northeast of Alliance on the Lake Erie, Alliance and Wheeling Railroad, and, with the next two places to be mentioned, in line with Alliance and Howenstein. These three places—Bests Station, North Benton, and Little Mill Creek, furnish exposures that must be combined in a single section in order to be rightly understood and without resort to elevation it would be almost impossible to rightly interpret the several outcrops.

A fourth of a mile east of the station and near the right hand side of the roadway a limestone occurs which was formerly burned for lime. It is not now exposed to its base, but is about 3 feet in thickness, apparently in one massive layer, tough, and rather dark gray or almost black in color. It lies at 1101 feet above sea and is the Vanport limestone as will appear later.

About 150 yards northwest on the opposite side of the road and on the Cornelius Smith farm the upper part of the Putnam Hill is seen in an excavation for a spring. It lies at 1084 above sea and is a light bluish gray in color, much lighter than the Vanport. Only 1 foot of it is exposed and its thickness unknown.

North Benton. This village lies 2 miles northeast of Bests and the hill above the town reaches an elevation of 1127 which is sufficiently high to carry both of the above limestones but 50 feet of the hill top is sandstone. A well at Mr. Hammond's barn just across the roadway from the brick church penetrates a limestone which may be seen outcropping in the roadway east of the barn and near the northwest corner of the cemetery. It lies at 1069 and is the Howenstein limestone. Its thickness is not seen at this point but is probably 2 to 3 feet. Mr. Hammond reports 4 to 5 feet of black shale on top of the limestone. Sandstone clearly succeeds the shale as may be readily seen in the roadway above the church.

Near the northeast corner of the cemetery and 29 feet below the top of the limestone the base of a bed of fireclay occurs. This fireclay marks the horizon of the Upper Mercer limestone but neither the thickness of the fireclay nor what overlies it is exposed here. Two hundred yards or more down steam loose blocks of limestone are seen and are thought to be from this horizon. Nearly a half mile northeast of the cemetery on the O. F. Henry farm this limestone is exposed at 1048 above sea at its highest point. It undulates sharply dipping 4½ feet in 50 yards. It

measures from 2 to 3 feet in thickness, is blue-black and very fossiliferous. Here it is directly underlain by 2½ inches of blue and yellow clay succeeded by 14 inches of coal.

This limestone is seen again outcropping in the roadway ⅓ mile southeast of the village.

About ¼ mile north of the village on Island Creek, and near stream level a bed of coal is found. The bed has been opened but found to be too poor to mine. It lies at 1012 feet above sea and appears to be the coal belonging to the Lower Mercer limestone although no limestone is found at this horizon in this vicinity. This coal is of no value further than aiding in identifying horizons and its relations will be considered in this connection with the outcrops on Little Mill Creek. At various places from the North Benton Cemetery, below the fireclay noted, loose micaceous sandstone in thin layers can be seen down stream to the outcrop of the above coal. This interval of about 36 feet appears to be composed largely of this kind of rock. The interval, however, at first appears too great to be that between the Mercer Limestones, but it will be remembered that the elevation of 1048 above sea is on a crest of the Upper Mercer and a sharp dip is seen. The trough in all probability reaches 1042 or less. Again were the Lower Mercer present with a thickness of 3 feet and resting directly upon the coal, which it does not always do, the interval would be still further reduced and within the limit seen at Howenstein.

Little Mill Creek. This stream flows into the Mahoning River from the east and with its mouth located about 1 mile north of the O. F. Henry outcrop and near the Portage–Mahoning County line. This stream is designated *Little* Mill Creek to avoid confusion with another Mill Creek in the eastern end of the county. One and one-half miles east of its mouth and 2 miles northeast of North Benton several outcrops of limestones occur along this stream and its branches. They are the Mercer limestones. The Upper Mercer occurs in typical exposure in a small ravine a few rods east of Mr. Simon Hartzell's barn where it is 2½ to 3 feet thick and dips sharply toward the south. At a medium point its elevation is 1037 feet above sea. This stone is blue-gray to blue-black and weathers to a rusty brown. About ¼ mile south of this point a thin coal is seen in the shale and clay pit of the Dustman Brothers Pottery Plant which lies at about 1075 above sea and apparently marks the horizon of the Howenstein limestone but no limestone is present. Only dark shale and drift clay overlie this coal.

About the same distance north of the Hartzell outcrop the Lower Mercer becomes a very conspicuous stratum in the sides and floor of Little Mill Creek. About 150 yards above the highway bridge on the north and south road this stratum forms a fall

in the stream over a conspicuous overhanging ledge which extends from bank to bank. No better outcrop of the Lower Mercer is found anywhere than occurs here. At the fall the stratum lies in two layers in immediate contact and without any parting. The lower layer is 7 inches thick and the upper 2 feet, 5 inches. It is rather tough, blue-black, and quite fossiliferous. In the south bank in the roadway it lies at 1022 above sea, at the lowest point seen a few rods above the fall it lies 12 feet lower or a dip of 12 feet in a distance of about 150 yards. If the inclination observed in the cliff a short distance above the fall may be taken to indicate a continuation of the dip up to that point then this limestone in its trough probably lies 20 feet lower than at its crest near the bridge.

On Turkeybroth, the north branch of Little Mill Creek, at a point 4 or 5 hundred yards above the fall this limestone again rises and becomes the floor of the Turkeybroth for some distance where it lies at about 1015. Near the top of the cliff a short distance above the fall the Upper Mercer again outcrops and is 3 feet, 1 inch thick. Its top lies 16 feet, 8 inches above stream. But it does not lie 10 feet above the level of the Lower Mercer's crest at the bridge. The Upper Mercer is again quite well exposed for several hundred yards in the sides and bed of the south branch of Little Mill Creek. About 200 yards above the fork this stratum is seen in the south bank at 9 feet above stream, blue-black, very tough, and 3 feet, 2 inches thick with 10 inches of coal $1\frac{1}{2}$ feet beneath it. Up stream the limestone soon becomes the creek floor and is seen to undulate gently now above water and now below and gradually rising toward the east. For considerable distances where the stratum lies a little below water level and having been swept clean, there is seen to be a top layer 2 to 4 inches thick, which is jointed so regularly as to look very like street paving. The jointing planes not being equal distances apart divide the layer into rectangular blocks 4 to 10 inches wide and 6 to 15 inches long. The jointing lines are very distinct and present a striking appearance in the still water between the crests. It would seem that the blocks might be lifted easily but so tightly do they fit that it is with difficulty that one is raised from between its fellows. This pavement layer is more carbonaceous, nearly black, less tough, and much more fossiliferous than the thick layer beneath.

At the point where this stream bends to the south the limestone disappears and is seen to dip sharply to the southward. It is not seen again for nearly a half mile, and then reappears rising above the stream bed at a point south of where it was last seen and lies 6 or 8 feet higher. This outcrop occurs about 200 yards below Mr. John Helsel's barn. Both of these limestones where exposed in the stream bed are seen to be jointed and lie in heavy

massive blocks. The banks of the stream for several hundred yards below the falls are strewn with huge blocks as if distributed for some giant masonry. The blocks often measure 8, 10 or even 12 feet in length.

As seen at the fall and below the Lower Mercer is underlaid by 4 feet of fire-clay and sandy shale but no coal. A short distance below the bridge this limestone dies out, shale appears, and coaly shale comes in at the horizon of the base of the limestone and further down becomes a definite bed of coal of 4 to 6 inches thickness. This coal is traceable with a sandstone cover all the way to the Mahoning River. At the forks of the highway and just above the first bridge over Little Mill Creek this coal is 1 foot thick, lies at 1024, and is overlain by shaly micaceous sandstone. At a point about midway between the above two bridges on this creek this sandstone was formerly quarried. The coal is seen to undulate and is certainly the coal referred to on Island Creek near North Benton which at that point lies at 1012 above sea. It is certainly the coal belonging to the Lower Mercer limestone but the latter is not seen anywhere to the westward on either Little Mill Creek or the Mahoning River as far up the river as the Benton-Deerfield highway. There is another thin coal to be noted, however, in this connection which may easily cause confusion. About 300 yards down stream from the mine on Island Creek and at the bridge east of Benton Station this coal lies in the creek bed at 997 above sea and about 8 inches thick. A third of a mile northwest in the river bank just below the railroad river bridge this coal is 7 inches thick and lies at 1000 above sea or 18 feet below rail on the bridge. It is seen at numerous other points on the Mahoning and on Little Mill Creek and at 15 to 20 feet below the Lower Mercer Coal. The intervening rock is largely sandstone. It is of interest to note here that two coals occur below the Lower Mercer limestone at Lowellville; a 2-inch layer 2 feet below, and an 18-inch bed 13½ feet below.

It now remains to combine the several outcrops of limestone seen in the Best's Station–North Benton–Little Mill Creek vicinity into one section. From the data given it is clear that the horizons of the Lower Mercer, Upper Mercer, and Howenstein are found at North Benton. The mean elevation of the Lower Mercer on Little Mill Creek is 1016, of the Upper Mercer 1037. The Lower Mercer coal near North Benton lies at 1012 and were the limestone present above it in usual thickness its elevation would be 1015. The Upper Mercer at North Benton lies at its highest piont at 1048 but its mean elevation is quite probably about 1043. The Howenstein as seen at the cemetery lies at 1069. What is seen on Little Mill Creek confirms the identification of horizons at North Benton, and the outcrops at North Benton are sufficiently close together to be grouped in a single

section without allowance for dip. Three of the five limestones are so far accounted for at elevations as follows: 1015, 1043, and 1069 above sea. Those at Best's Station are to be added, but being 2 miles away dip must be considered. The nearest point for comparison of elevations of all five limestones is at Alliance. The outcrops at Best's Station are about 4½ miles from Alliance and those about North Benton about 7 miles, except the Howenstein outcrop which is about 6½. Comparing the elevations of the lower three at the two places, they are as follows:

	Alliance	North Benton	Difference
Howenstein	1008	1069	61
Upper Mercer	966	1043	77
Lower Mercer	945	1015	70

It appears at once that there is a dip toward Alliance from North Benton whatever it may be in any other direction. For the Mercer limestones it is 10 and 11 feet per mile, for the Howenstein a little over 9 feet per mile. It will be remembered, however, that the latter stratum lies relatively higher at Alliance than in the Nimishillen valley. Comparing the upper two limestones likewise they appear as follows:

	Alliance	Best's	Difference
Vanport	1081	1101	20
Putnam Hill	1032	1084	52

The first difference is not what would be expected from the dip found in the first three limestones, but the second corresponds very well giving a dip of about 11½ feet per mile. The Vanport clearly lies considerably lower relatively than at ony other place found, and its dip of less than 5 feet per mile is not representative of the general dip of the strata. Therefore in combining the outcrops at Best's and Benton a general dip of about 11 feet per mile must be used in adjusting the interval between the Howenstein and Putnam Hill limestones, and combining the outcrops for a section at North Benton the following elevations represent the horizons of the several limestones:

Vanport	1125
Putnam Hill	1106
Howenstein	1069
Upper Mercer	1043
Lower Mercer	1015

It will be observed at once that the elevation of 1125 for the Vanport does not conform to the 11 foot dip, but it is quite probable that it lies at about 1125 at this point since it lies only 17 feet above the Putnam Hill at Best's Station, which strongly suggests a thinning of intermediate strata in this region. It is true that the interval between the Lower Mercer and the Vanport would thus be only 110 feet, while the same interval at

Howenstein is 147 feet, at Alliance 136 feet, in central Mahoning County 122 feet, and at Lowellville 133 feet.

Probably the most striking fact is the rise in the strata toward Benton since this is in line with Howenstein and Alliance. But as before the writer accounts for this occurrence in part on the ground that an anticline lies to the east of Alliance and in going from this place to North Benton the northwest slope of the anticline is ascended.

MEANDER CREEK AND TRIBUTARIES.

This stream and its tributaries arise in the central part of Mahoning County and furnish the next good exposures of limestone.

Ellsworth. A half mile south of the village of Ellsworth and just below the fall at Club Lake in the bed of the west branch of Meander Creek the Lower Mercer occurs at 1023 feet above sea, is 3 feet thick and possesses its usual characters. In the south bank of this stream near the highway bridge an opening has been made into the coal belonging beneath this limestone. The coal was not seen but lies at about 1018. About ¼ mile below the highway bridge a 9-inch coal is exposed in a cliff with sandstone above it and lying at 1003 feet above sea. This is certainly the same coal seen on Little Mill Creek and on the Mahoning River. The elevation and interval between the coals are almost identical although the two localities are about 8 miles apart.

A few hundred yards below the above cliff on the south side of the creek occur conspicuous clay banks rich in beautiful crystals of selenite which have given the obscure village of Ellsworth a place of prominence with geologists and museums far and wide. The clay is a gray talcose glacial deposit.

At the Club Lake fall 14 feet above the limestone thin streaks of coal occur at the base of a massive sandstone. It is clearly the Upper Mercer coal but with its limestone displaced by the massive, coarse grained sandstone which contains numerous impressions of lepidodendrids, sigillarids, and calamities. The currents that prevented the formation of the limestone swept down the coal plants and entombed them in sand. No better display of fossil plants in sandstone is known to the writer than occurs in this stratum.

The bluish gray shale beneath the sandstone contains great numbers of beautifully preserved fern leaves and other plants.

Diehl Creek. At a point about 2 miles east and slightly south of Club Lake on Diehl Creek, a tributary of the middle branch of Meander, the Lower Mercer is again seen in the sides and bed of the creek and presenting the same appearance as seen on Little Mill Creek, but with less undulation. The stratum lies at 1024 feet above sea, is 2 feet 5 inches thick and in two layers, the

lower one being 5 inches. The two layers are a quite constant expression of this limestone throughout Mahoning County and wherever a good exposure of the entire thickness is seen this character is present. I. C. White in his report on Mercer Co., Pennsylvania, pointed out this feature, as noted in the first part of this paper. The most westerly point at which this feature has been observed in Mahoning County is at the fall on Little Mill Creek. The same character occurs at Shew's Mill in Stark County.

Lower Outcrop. On the middle branch of Meander Creek at a point about two-thirds of a mile southwest of the Diehl Creek outcrop and a short distance south of Mr. John Lower's barn the Upper Mercer is exposed in a ravine and lies at 1040. The stratum is not well exposed but is about 2 feet in thickness and is overlain by 33 inches of coal which has been mined to a small extent. The subjacent strata were not seen. This point is 2 miles southeastof Club Lake where the Upper Mercer Coal lies at 1037. These elevations indicate practically horizontal strata. The interval between the limestone and the coal at the lake is practically the same as that between the limestone on Diehl Creek and the limestone near the Lower barn. One would think dip must be counted but these elevations and measurements forbid it.

Bingham Outcrop. One and one-fourth miles west of the Lower outcrop and three-fourths of a mile a little east of south of Club Lake on the farm of E. W. Bingham a limestone lies at 1072 feet above sea. It is 15 to 18 inches thick and overlies a bed of coal which was formerly mined to a limited extent. This is 32 feet higher than the Upper Mercer and is certainly the Howenstein limestone. It lies 7 feet higher than the top of the heavy sandstone at Club Lake. North of the Bingham residence and on the farm of C. E. Bowman a bed of coal lies a few feet above the top of this standsone and is undoubtedly the same coal as on the Bingham farm.

Above the Howenstein limestone lies sandstone as seen in the hillside above the coal mine and in the roadway near the Bingham residence. Succeeding the massive sandstone a black coaly shale appears with its base at 1096 above sea. Mr. Bingham states that it is 13 feet thick and underlies much of the hill above the limestone and that it has been penetrated by drill in numerous places in the hope of finding a good bed of coal. A heavy coarse sandstone succeeds this shale to the top of the hill or to an elevation of about 1150. The structure of this hill from the limestone up is of much importance in the interpretation of the next outcrops to be noted.

Unger Outcrop. On Meander Creek one-fourth mile southwest of the southwest corner of Canfield Township and on the Unger farm an outcrop of limestone occurs a few hundred yards

southeast of the Unger barn. The stratum is black and 18 inches thick lying at 1082 above sea. This exposure is about 1½ miles south, and 2¼ miles east of the Bingham outcrop, and lies 10 feet higher. As noted in the Lower outcrop there is no evidence of dip in this locality toward the south or south-east so far as the writer has found. A few hundred yards above the Unger outcrop and directly in the southwest corner of Canfield Township on the Ewing farm a bed of coal lies at 1115 feet above sea and a few feet beneath this a second bed. The top of the upper bed is 33 feet above the Unger limestone, and the bottom of the 13 foot black shale on the Bingham farm lies 24 feet higher than the Bingham limestone or the *top* of the shale 37 feet higher. Above the limestone at both places there is sandstone; above the black shale on the Bingham farm and above the coal on the Ewing farm sandstone occurs. With no evidence of dip and with close correspondence of the strata in elevations and character, the conclusion that the limestone at Unger's is the Howenstein and that the Ewing coals are the equivalent of the black shale at Bingham's is inevitable. The coal on the Ewing farm was identified by Dr. Orton as the Canfield cannel coal, and the fragments of limestone found at the opening of the Ewing mine as the ferriferous limestone. [Ohio Geol. Sur. Vol. V, p. 31.] He further indicates that the dip is 15 or 20 per mile toward the southeast in this locality. Upon what is it based is not stated. The writer finds only evidence of little or no dip at all, and is unable to regard the Ewing coal other than that beneath the Putnam Hill limestone, and that the fragments of limestone found by Dr. Orton belong to that stratum. A comparison of the limestones, coals, and their elevations on the east side of Canfield Township with those at Lowellville leads to no other conclusion than that the Canfield Cannel Coal is the coal beneath the Vanport limestone as Dr. Orton identified it. The following are the elevations of the limestones on Meander Creek and those on the east side of Canfield Township:

Meander Creek	Canfield Township
(5) ————	(5) Canfield Cannel Coal 1151
(4) Ewing Coal 1115	(4) Fireclay 1101
(3) Howenstein 1082	(3) Howenstein 1078
(2) Upper Mercer 1040	(2) Upper Mercer 1050
(1) Lower Mercer 1024	(1) Lower Mercer 1029

This table is the writer's interpretation of his findings based upon the number of strata, their elevations and their intervals. (1), (2), and (3) correspond well. (4) on the east side of Canfield clearly lies lower than usual but unmistakable.

The Ewing coal certainly appears to mark the Putnam Hill horizon in the southwest corner of Canfield Township.

The interval between (2) and (5) on the east side of the township is seen to be 101 feet, and it may be reasonably expected that about the same interval would occur on Meander Creek. At Howenstein it is 119 feet, at Alliance 115 feet, at Lowellville 115 feet. Since the Ewing ontcrop is nearer east Canfield Township with the 101 foot interval, a 101 foot interval on Meander Creek seems entirely reasonable. The horizon of No. (5) on Meander Creek then would be about 1141 feet above sea, or about 26 feet above the Ewing coal.

Recourse to another measurement may be taken which tends to confirm the conclusion that the horizon of the Vanport lies higher than the Ewing coal. From the data on the strata at Alliance and southward and with the Upper Freeport limestone lying at 65 feet above the Middle Kittanning coal in the Minerva Tunnel-cut it will be seen that the interval between the Vanport and the Upper Freeport limestones is 121 feet in that locality. The Upper Freeport limestone is found on the Canfield-Greenford highway in the Goodman Hill at 1256 feet above sea. This point is one mile a little south of east from the Ewing mine, and the limestone is readily recognized as the Upper Freeport by its brecciated character and a minute coiled worm-like fossil in great numbers. The interval between the Ewing coal and the limestone is 141 feet. Dip, if there were evidence of it in this locatliy, would increase this measurement. As it is, it exceeds the first measurement by 20 feet which is near the interval between the Ewing coal and the horizon at which the previous calculation would place the Canfield Cannel or the coal beneath the Vanport limestone.

If the Ewing coal were the Canfield Cannel and the limestone found by Dr. Orton the Vanport, then the interval between the Lower Mercer and the Vanport limestone on Meander would be only 93 feet which is considerably less than the average interval.

Beardsley Outcrop. On the east branch of Meander Creek and about 1 mile northwest of the County Infirmary an outcrop of the Lower Mercer occurs on the farm of Edward Beardsley. Its average thickness is about 3 feet and was formerly quarried extensively and shipped to the furnaces at Leetonia. At 12 to 18 feet below the limestone a bed of coal is found which reaches a thickness of 3 feet and has been mined to a considerable extent for local use. It thickens and thins rapidly and at one point is seen to be only 13 inches. It is certainly the same coal seen below Club Lake and on Little Mill Creek. The limestone lies at about 1021 feet above sea.

Ripple Outcrop. South of West Austintown one-half mile along the Erie Railroad and just above the residence of Mr. John Ripple the Lower Mercer outcrops in the highway at 1028 above sea. In the mine beside the old Paint Works the limestone

measures 3 feet 6 inches. The rich bed of iron ore above it was formerly mined and used in the manufacture of paint.

This limestone is being burned for fertilizer on the John Fitch farm near West Austintown.

McMahon Outcrop. About 1¼ miles southeast of the Ripple outcrop an exposure of limestone occurs on McMahon Run and on the farm of Ambrose McMahon. The full thickness is not now exposed but reported to be 2 feet or more in a coal shaft at this point. Drillings close around gave a thickness of 2½ to 3 feet. In one hole reported by Mr. McMahon a 2-foot coal was penetrated 10 feet above the limestone. As seen in the run the limestone lies at about 1040. The coal at the shaft lies 25 feet below the limestone or at 1015, but in one of the drill holes at 20 feet below that stratum. The limestone is overlain by a rich bed of iron ore as at the Ripple outcrop and would seem from all the data to be the Lower Mercer although 12 feet higher than at previous outcrop. Undulation will easily account for this difference. The 2 foot coal above it would seem to be the coal belonging to the Upper Mercer but no trace of this limestone or its coal is seen in the run above the shaft where the next 35 feet of strata are exposed.

Smith Corners. At Smith Corners about one mile a little south of east from the McMahon outcrop William Gardner penetrated a limestone of about 18 inches thickness at 1090 above sea. The dip toward the southeast in eastern Mahoning County is only about 5 feet per mile, the interval therefore of 55 feet indicates rather clearly that this is the Howenstein limestone. The McMahon outcrop, Smith Corners and Poland are nearly in line and the matter of dip in that direction will be considered further under Poland outcrops.

MILL CREEK AND TRIBUTARIES.

This stream empties into the Mahoning River at Youngstown after crossing the eastern end of Mahoning County from south to north. Its bed for more than 7 miles from its mouth lies below the horizon of the Lower Mercer limestone, and the scanty outcrops of the limestones, therefore, are found on its tributaries.

Facodi Outcrop. In the first ravine to the east above the fall at the old Lanterman Mill on Mill Creek, the Lower Mercer is first seen on the land of Una Facodi at 1010 feet above sea. The exposure is poor and the thickness not seen. It is underlain by gray sandy shale and flaggy sandstone down to Mill Creek. This sandstone is the Upper Massillon and it constitutes the rock walls of Mill Creek gorge.

Lanterman Outcrop. About one-fourth mile south of the Facodi outcrop and on the German Lanterman farm the Lower Mercer outcrops in a ravine which crosses the north and south

highway. It was formerly quarried on both sides of the ravine for some distance and burned for lime. At this point it lies at 1007 above sea.

Baldwin Outcrop. A half mile south of the last outcrop and on the Jesse Baldwin farm this same stratum may again be seen in a ravine in the rear of the Baldwin residence where it is 2 feet, 3 inches thick and overlies 18 inches of coal which was formerly mined on this farm to a limited extent. By topographic map the limestone lies about 1010 above sea. About 200 yards east of this point and across the road fragments of a limestone are lifted in plowing and the stratum would seem to lie about 1050 above sea.

Davis Well. This elevation would seem to be confirmed by penetrating a limestone at 1050 in a well at the residence of George E. Davis on the Youngstown-Boardman pike. The Davis well is ½ mile southeast of the Baldwin outcrop. It would seem that the second limestone is the Upper Mercer. If it is the Upper Mercer the interval is greater than anywhere else found.

Moyer Spring. At a point ½ mile south of the Davis well and 1 mile southeast of the Baldwin outcrop a limestone is found in a spring at the sawmill on the Samuel Moyer farm and lies at 1030 above sea.

Geiger Well. On the C. T. Geiger farm ½ mile southeast of the Moyer spring a limestone was penetrated in a test-well at 9 feet lower than in the Moyer Spring.

Walters Well. At the residence of E. C. Walters 1 mile southwest of the Moyer Spring a limestone occurs in the well at 1018 above sea and about 500 yards northwest of the Walters residence the Lower Mercer is exposed on Mill Creek at about 1000 above sea. As seen here this stratum is 2 feet, 4 inches in thickness and presents its usual characters. It directly overlies a black coaly shale varying from 0 to 18 inches in thickness.

Greenhouse Hill. Returning to the vicinity of Youngstown a third limestone is found ¾ mile east of the Lanterman outcrop and ¼ mile north of the township line on the Youngstown-Boardman pike. It outcrops in the gutter on either side of the pike a little above the greenhouse. The limestone is dark blue, fossiliferous, 2 feet thick, underlain by coaly shale, and lies at 1076 elevation. No other outcrop of it was found in this locality. The Lanterman, Baldwin, Davis well, and Greenhouse Hill limestones are sufficiently close together to conclude from them that the limestones found at these points are the Lower Mercer, Upper Mercer and the Howenstein.

Dr. Newberry in his report on Mahoning County gives a section of a boring made near the south side of Youngstown Township in which three limestones were penetrated. [Ohio. Geol. Sur. Vol. III, p. 803.] They are between tops, lower and middle

35 feet, middle and upper 39 feet. These are without doubt the same three limestones noted above. By boring the interval between the upper and lower is 74 feet; as observed in outcrop 66 feet not counting 4 or 5 feet for dip. Furthermore, only the hilltops on the south side of Youngstown Township reach an elevation of 1100 feet, and Greenhouse hill is one of them with the Howenstein at 1076 and near its top. Dr. Orton regarded this upper limestone as the Putnam Hill. [Ohio Geol. Sur. Vol. V, pp. 29–30.] But a comparison of the various sections unmistakably indicates that it is the Howenstein. The several other occurrences of limestone at various elevations as given above indicate that pronounced undulation exists in this locality in the lower limestones.

Indian Creek Outcrops. This stream is a tributary of Mill Creek and has cut a deep course in the southeast quarter of Canfield Township exposing coals and limestones.

On the Jonas Christman farm in the bed of Indian Creek at a point ½ mile west of the township line the Upper Mercer lies at 1039 feet above sea, is over 2 feet thick, and rests upon 14 to 18 inches of good coal. The limestone was formerly quarried and burned with the coal. On the same farm and on the south side of the creek a bed of coal was formerly mined which carries lenticular masses of limestone lying at 1064 above sea. These lenses are often beautiful septaria 12 to 18 inches in diameter and quite fossiliferous. The septarian character is well shown in a ravine on the north side of the creek several hundred yards above the outcrop in the creek bed. The coal underlying the limestone lenses is 18 to 24 inches thick and was formerly mined on the William Swanston farm. Seventy-three feet above the lenses lies the Canfield Cannel Coal at about 1139 above sea.

Dr. Orton identified these limestones and coals as the Lower and Upper Mercer and gave an interval of 85 feet between the coal under the limestone lenses and the cannel seam. Undulation will easily account for difference in interval, but the lenses are certainly the Howenstein limestone as will appear a little later.

On the Canfield-Boardman road in the Heintzelman hill ¼ mile west of the Canfield-Boardman line a bed of fireclay occurs at 1072. About 300 yards northwest of this point a mine has been opened in an 18 inch coal which carries limestone lenses lying at 1078 above sea. This is beyond question the same horizon noted on Indian Creek 1 mile south.

Neff Run Outcrop. About 300 yards northwest of this mine in a ravine on Neff Run, a tributary of Indian Creek, a 2-foot limestone occurs on the Martin Neff farm and rests directly upon a 20-inch coal. This limestone lies at about 1050 above sea. Recently Mr. Neff explored for the Sharon coal and in a drill hole close beside the run and below the horizon of the above limestone

penetrated 61 feet of drift. A little north of the run and above the limestone two limestones were penetrated. The upper one 2½ feet thick with 16 inches of coal directly beneath it, the lower one 3 feet thick and no coal beneath, and 21 feet between tops of the limestones. These facts are perfectly clear. The lenticular limestone is the Howenstein; the outcrop in the ravine at 1050, and the upper one in the drill hole, is the Upper Mercer; the 3-foot limestone in the drill hole is the Lower Mercer.

The three limestones on the east side of Canfield Township are in harmony with the section on Meander Creek 5 miles to the west; they agree perfectly with the section on Yellow Creek 5½ miles to the east; they are in entire accord with the findings in the vicinity of Youngstown 4 miles northeast; and they answer closely to the facts found on McMahon Run and at Smith Corners 4 or 5 miles northwest.

The section on Neff Run with the Lower Mercer at 1029, the Upper Mercer at 1050, and the Howenstein at 1078 combined with the measurement between the Howenstein and the cannel coal as found on Indian Creek gives the entire interval between the Lower Mercer and the Vanport horizons a measurement of 122 feet. The interval of 73 feet between the Howenstein and the cannel coal was nowhere found well exposed, but somewhere near the middle of it we would expect to find some trace of the horizon of the Putnam Hill limestone. No trace was seen in outcrop but in a drill hole on the Neff farm a few hundred yards north of the old mine in the cannel coal on the William Swanston farm a driller reports 8 feet of fireclay 50 feet below the cannel coal. The top of this clay certainly marks the Putnam Hill horizon. At 119 feet below the cannel coal a 3-foot limestone was penetrated which is undoubtedly the Lower Mercer. The following section, therefore, indicates the relations of the limestones or their horizons for the Neff Run locality on the east side of Canfield Township:

Vanport limestone (cannel coal)	1151
Putnam Hill limestone (fireclay)	1101
Howenstein limestone (lenses)	1078
Upper Mercer limestone	1050
Lower Mercer limestone	1029

DIP OF STRATA IN CENTRAL MAHONING COUNTY.

The matter of dip presents some points of interest in central Mahoning County. The Lower Mercer dips southeast from McMahon Run to Indian Creek about 22 feet in 5½ miles or about 4 feet per mile. The Howenstein dips more south than east between Smith Corners and Indian Creek 26 feet in 4½ miles. The average dip is therefore seen to be about 5 feet per mile in this direction.

From Lower Outcrop nearly due east to Indian Creek the Upper Mercer dips 1 foot in 5½ miles. The Howenstein dips in the same direction from Bingham Outcrop to Indian Creek 8 feet in nearly 7 miles. The Lower Mercer rises from Club Lake to Neff Run in a direction 7½ miles east and 1 mile north 6 feet in 7½ miles. It is seen at once that the strata lie almost horizontally from east to west in the center of the county.

From Neff Run to Lanterman Outcrop more north than east the Lower Mercer falls 19 feet in 3½ miles, whereas it would be expected to rise judging from its position to the west of Neff Run. From the same run to Davis well very nearly northeast the Upper Mercer lies horizontally having an elevation of 1050 at each place and 3½ miles between. From Neff Run to Greenhouse Hill exactly northeast the Howenstein falls 2 feet in 4 miles. The average for the three strata is seen to be about a 2-foot fall per mile. In a direction so much north of east a rise of several feet per mile would be expected.

From the Beardsley Outcrop to Neff Run in a direction 1½ miles south of east the Lower Mercer rises 8 feet in 4 miles. Further comment on the dip and position of the strata in central Mahoning County will be made in connection with the Yellow Creek and Lowellville sections.

YELLOW CREEK.

This stream is a tributary of Mahoning River and flows northward nearly parallel to Mill Creek half way between the latter and the state line. It has a fall of about 210 feet in 5 miles and its rapid current has cut a deep gorge from the village of Poland to its mouth at Struthers. Accordingly unusually good exposures of the Potsville formation are afforded.

Poland Outcrops. At the village of Poland two outcrops of limestone occur. The first is seen on the north side just below the cemetery forming a conspicuous ledge and water fall in Yellow Creek. It is the Lower Mercer and lies at 990 feet above sea. The stratum presents here that peculiarity of two layers noted elsewhere. The upper layer measures 2 feet, 3 inches and the lower 7 inches. Resting directly upon the heavy bed is a 2-inch very impure layer of limestone of cone-in-cone structure which breaks easily and shows this peculiar structure quite admirably. The heavy bed is bluish gray, tough, fossiliferous, and sparkles with crinoid stems and calcite crystals. The limestone is directly underlain by black carbonaceous shale which is extremely fossiliferous. Seventeen feet of yellowish-gray flaggy sandstone overlies this limestone at this point.

One and one-half miles from the Mahoning River the City of Youngstown has built a dam on Yellow Creek, the head water of which is found a few hundred yards below the above outcrop.

In a cliff at the head of still water the Lower Mercer is again well exposed as a conspicuous middle stratum of 3 feet thickness in the cliff face and lying at its top 9 feet above dam level. A 5-inch impure cannel coal lies 4½ feet below its base. In the second ravine south of the spillway the Lower Mercer is again seen and lies 4 feet higher than in the above cliff, a mile distant. The dam level is about 980 feet above sea.

The second limestone at Poland outcrops on the south side of the village in the creek bank in the rear of the Presbyterian church. The stratum is clearly the Upper Mercer and lies at 1013 above sea. As seen here it rises a few feet above, then sinks beneath the level of the Poland Mill Dam.

Burgess Run Outcrop. One and one-quarter miles south of Poland on Burgess Run, a tributary of Yellow Creek, a third limestone outcrops at 1050 in the run bank near the highway bridge and on the farm of D. W. Walker. The stratum is nearly black and 2 to 2½ feet in thickness. It is underlain by 18 inches of coal 15 inches of which is cannel. The limestone is overlain by sandstone as seen above the highway. This is clearly the Howenstein limestone although it lies lower than in the outcrops noted on Neff Run, at Smith Corners and in Greenhouse Hill. But it is also noticed that the Mercer limestones lie correspondingly lower.

DIP OF STRATA FROM CENTRAL TO EASTERN MAHONING COUNTY.

Poland is directly east of the Neff Run outcrops 5½ miles and a comparison of the elevations of the three strata at once reveals a dip toward the east which was not found the case across Canfield Township.

Neff Run		Poland	
Howenstein	1078	Howenstein	1055
Upper Mercer	1050	Upper Mercer	1013
Lower Mercer	1029	Lower Mercer	990

The Howenstein is not found at Poland but the dip southeast from Greenhouse Hill to Burgess Run is 5 feet per mile, hence the horizon of this limestone is about 1055 at Poland. These elevations show that the Howenstein dips toward the east slightly over 4 feet per mile, the Upper and Lower Mercer 7 feet per mile.

The elevations at Poland may be compared with one other set. The outcrops south of Youngstown and those at Poland lie in a line extending northwest and southeast.

Youngstown			Poland	
(Greenhouse Hill)	Howenstein	1076	Howenstein	1055
(Davis Well)	Upper Mercer	1050	Upper Mercer	1013
(Facodi)	Lower Mercer	1010	Lower Mercer	990

The distance between the first two points is 4 miles hence the Howenstein dips about 5 feet per mile which it is seen to do between Greenhouse Hill and Burgess Run. Between the second two points the distance is 3½ miles and the dip 11 feet per mile. This is undoubtedly due to this limestone lying much farther from the Lower Mercer at Davis Well than is usual, and therefore not representative of the general southeasterly dip of the strata. The Howenstein and Lower Mercer may be taken as more correctly expressing the general dip. Between the third two points the distance is 4½ miles with a dip of 4½ feet per mile.

CANFIELD ANTICLINE.

It will be recalled that in the interpretation of the Alliance section that facts seem to point to the existence of a fold lying east of that city. The writer believes that the data found in Mahoning County fully warrant this conclusion. The fold is a broad low one and seems to lie through the center of the county with Canfield somewhere near the crest. The horizons of all the limestones lie higher in Central Mahoning County than at Alliance or Poland. The existence of nearly horizontal strata from west to east in Canfield Township, and of marked dip in the same direction from the east side of the township toward Poland indicate such a fold. The fold is sufficiently low that the normal dip of the strata toward the southeast from Ellsworth and northwestern Canfield township is overcome causing the strata to lie almost horizontally, or with a slight rise in that direction. The unexpected fall in the strata toward the northeast from Neff Run, where a rise would be looked for, indicates a dying out of the fold in the vicinity of Youngstown. The rise in the strata from Alliance toward North Benton is believed to be due in part to ascending diagonally the west slope of this fold. Lastly, southeast of Alliance and in northwestern Columbiana County oil is found in many wells. Four miles southeast a good producing field is found. Six miles south and 2 miles east in the vicinity of Homeworth two other fields are found. Again, 8 miles southeast of Alliance a gas field occurs in the vicinity of North Georgetown. The position of these fields shows a general northeast and southwest direction. A distance of 4 miles from northwest to southeast across this belt of fields conforms exactly to facts found in central Mahoning County and the fields are certainly associated with the Canfield Anticline.

Gorge Outcrop. The three limestones already considered on this creek are the ones to be expected but another calls for attention. It lies below the Upper Massillon sandstone and therefore appears only in the lower part of the Yellow Creek gorge. This limestone is seen in the creek bed and in the north wall of the gorge about 4 or 5 hundred yards below Yellow Creek Dam,

and lies at about 884 feet above sea. It is black, tough, very hard, without fossils, somewhat concretionery in appearance, and 6 to 15 inches in thickness. The limestone lies 6 feet above stream level as seen in the cliff and near the middle of a 12-foot black and gray shale. Two thin seams of coal are seen above the limestone, one at 9½ feet and the other at 15 feet above, and seem to hold the horizon of the Quakertown coal.

The limestone lies 109 feet below the top of the Lower Mercer as seen in the ravine south of the spillway. Nearly 80 feet of the interval between the two limestones is occupied by the heavy sandstone which is very unevenly bedded and in places sinks down cutting out the upper coal.

Further comment on this limestone will be made in connection with the Lowellville section.

LOWELLVILLE SECTION.

This village is situated in the gorge, or deep narrow valley of the Mahoning River 1 mile west of the state line. Water level at the Lowellville River Bridge is 807 feet above sea and the borders of the gorge reach 1140 feet above or more. In places the gorge borders are less than 1 mile apart at 300 feet above the river and as would be expected numerous deep ravines trench the steep sides of the valley.

Furnace Run may be taken as typical of these ravines and as affording a typical section in the vicinity of Lowellville. This ravine lies on the south side of the river and immediately beside the highwav leading south from the village. The mouth of the ravine is seen at the furnaces of *The Ohio Iron and Steel Company*.

Ascending this ravine the Mississippian-Pennsylvanian unconformity is seen at different places and with hilltops of the dove-colored Cuyahoga more than 100 feet above the river. About 200 yards east of the mouth of this ravine a mine is opened in the Sharon coal which lies at 848 feet above sea and lying in a narrow trough between ridges of the Cuyahoga formation. In the bed of Furnace Run about half-way between the Pennsylvania Railroad and its switch leading to the stone quarry the first limestone is found lying at 912 above sea. Further mention of this limestone is deferred to the close of the discussion on the Lowellville section. At the lower end of the culvert under the above switch the Lower Mercer limestone occurs in the ravine bed at 995 feet above sea. It is 2 feet 6 inches thick and a dark bluish-gray in color. A 2-inch coal occurs 2 feet below it and an 18-inch bed 13 feet 6 inches below as seen 50 yards below the culvert. The 18-inch coal seems to be the same bed found on Meander and Little Mill Creeks. The limestone is overlain by iron ore.

The Upper Mercer is seen directly above the preceding limestone at the culvert, and lies at 1020 feet above sea. It is 2 feet 4 inches thick is slightly darker in color and contains the same fossils found in the Lower Mercer, and is immediately underlain by 15 inches of coal.

At 23 feet above the latter limestone or at 1043 feet above sea a thin bed of coal occurs which ranges from 3 to 6 inches in thickness as seen at several outcrops along the east side of the ravine. This is undoubtedly the coal seen beneath the Howenstein 4 miles southwest on Burgess Run and the representative of the coaly shale beneath that limestone seen on Greenhouse Hill 6½ miles a little north of west. The interval between the Upper Mercer and this coal is chiefly shale and contains two other coals. The first is 14 inches thick with only 2 feet 10 inches between it and the limestone. The second coal is 5 inches thick with its top 7 feet 10 inches above the limestone. Coal so close above a limestone is unusual. But it will be remembered that this is exactly the case in the Lower outcrop of this same limestone, and black coaly shale is found directly above the same stratum on Little Mill Creek at the point where it turns southward. Almost an exact duplicate of the facts found on Furnace Run immediately above the Upper Mercer is found on Little Mill Creek. Two beds of coal with clay and shale beneath each occur at the former place and two beds of black or coaly shale with clay and shale beneath each occur at the latter. This peculiarity of the Upper Mercer being sandwiched between two coals is not known to the writer to occur outside of Mahoning County.

At 1078 feet above sea another coal and fireclay is found. It is exposed in the roadway about 50 feet south of the highway bridge over the switch to the quarry. It is also exposed in the switch cut east of the bridge near the crusher, and again in the ravine about 300 yards southwest of the highway bridge. At the latter point it is 5 inches thick but thinner in the others and is underlain by 2 to 3 feet of clay and sandy shale which grades quickly in coarse shaly sandstone the latter filling the interval down to the next coal below. This coal and fireclay certainly mark the horizon of the Putnam Hill limestone. The sandstone between these two coals is in harmony with facts found on Burgess Run, Neff Run, at Smith's Corners at the Bingham outcrop, the Ewing outcrop, and at North Benton; or in brief, sandstone prevails between these two horizons through Mahoning County.

The coal at the horizon of the Putnam Hill limestone is the last noteworthy stratum to be seen at the head of the ravine. But 200 yards to the left of the ravine and at the top of the hill the extensive quarry in the Vanport limestone occurs. This stratum shows marked undulation. The top as seen at the

north side of the quarry at the mouth of the quarry drain-tunnel lies at 1115 above sea with a thickness of 12 feet. The thin coal accompanying the limestone, the "Scrubgrass" of Pennsylvania and the "Canfield cannel" of Ohio, lies immediately beneath it at 1103 above sea. In the drain ditch leading to the tunnel and 110 yards distant the same coal lies at 1120½ feet above sea, the limestone making an equal rise. This is the greatest elevation at which the coal was found. In the highway 150 yards south of the northwest corner of the quarry the greatest height of the limestone is found at 1138 feet above sea, but the limestone is 16 feet thick at this point. The average elevation is about 1128 feet above sea, and the average thickness about 14 feet.

As seen at the tunnel mouth the lower 8 feet of the limestone have a dark blue color and are less pure than the upper part. The upper 4 feet are a much lighter blue, purer and lie in better defined beds than the lower part. As seen in the southwest corner of the quarry the first 3 feet 5 inches of the limestone are shaly, blue in color and becoming firmer toward the top. The next 4 feet 4 inches are bluish-gray, darker below and lighter above, and in 4 fairly definite layers. The upper 8 feet 2 inches are gray with a bluish tint below, and in 11 fairly definite layers but not generally continuous. They often split into more layers, are only fairly tough and break into rather cubical blocks.

This limestone as it occurs at Lowellville is exceedingly fossiliferous and contains more species of fossils than any of the other limestones or possibly more than all the others combined. It is especially rich in gasteropods.

At every point where the top of this stratum is exposed it shows the smoothing, scratching, and grooving of glacial action. This limestone has been quarried for many years for use in the furnaces, and at present is being quarried extensively on the W. M. Arel farm.

One-half mile south of the quarry on the T. M. Moore farm openings in the Lower Kittanning coal may be seen at 1177 feet above sea. Considerable coal was formerly mined for local use but the mines have long since been abandoned. The entire interval between the top of the limestone and the top of this coal is covered.

The several horizons of limestone occurring below the Lower Kittanning coal down to, and including the Lower Mercer have been considered at numerous points across the two counties. We may now turn to a consideration of an earlier Pennsylvanian limestone than the Lower Mercer, the presence of which has been noted at several points. As stated at the beginning of the Lowellville section this limestone is seen in the ravine bed about midway between the furnaces and the switch leading to the quarry and at its highest point is 912 feet above sea. It lies 83

feet below the Lower Mercer limestone and 64 feet above the level of the Sharon coal at the base of the shaft. Its position seems to be about the horizon of the Quarkertown coal, but the only suggestion of an associated coal is a considerable thickness of black shale overlying it, which is quite fissile, fairly tough and lifting in broad sheets particularly the first few feet above the limestone. About one foot of the shale above the limestone is somewhat calcareous responding readily to acid, and suggests that at no great distance it may become limestone. This black shale is in harmony with the gray and black shale with the two thin seams of coal found above the limestone in the Yellow Creek gorge.

Being covered the character of the strata immediately beneath the limestone was not seen. A little below, however, massive layers of sandstone appear which are certainly the upper part of the Lower Massillon sandstone, or Lower Connoquenessing of Pennsylvania. The limestone is black, very hard, tough, and apparently in one layer. It is 2 feet or more in thickness—the full thickness not being obtained due to a sharp dip down stream concealing its base. It is very fossiliferous, the white shells and crinoid stems presenting a striking appearance in the black matrix. A few species of brachiopods and fragments of crinoid stems predominate. The latter are often 6 or 8 inches long, as they also are in the Vanport in the quarry above, and lying horizontally with the section markings showing plainly they somewhat resemble worms, and the uninitiated point them out and confidently inform one that they are petrified worms.

Newberry in his report on Mahoning County, and in a section on Grindstone Run indicates the presence at this horizon of a "Dark silicious limestone" 1 foot in thickness. [Ohio Geol. Sur. Vol. III, opp. p. 804.] He nowhere else describes or mentions it so far as the writer is aware.

It will be recalled that a black limestone outcrops in the Yellow Creek gorge at 884 feet above sea. This outcrop is about 2½ miles west of Furnace Run, and while it lies 28 feet lower than the outcrop on the latter run it is certainly the same stratum.

In a test well on the C. T. Geiger farm located near the Youngstown–Boardman pike and about 1 mile north of Boardman Center and 3¾ miles due west of the Yellow Creek outcrop, a 3 foot black limestone was reached at 910 feet above sea. It lies 111 feet below the Lower Mercer limestone and 47 feet above the Sharon coal which is 2 feet thick in this well and lies at 863 feet above sea.

It will be recalled that in the Alliance section an unknown limestone of 5 feet thickness was struck at 882 above sea and at

63 feet below the Lower Mercer. A 2 foot coal also occurs in the Alliance well at 60 feet below this limestone.

Mr. Thomas Hyland, a well driller of Columbiana, Ohio, reports to the writer that at numerous points south of Youngstown and as far as 10 or 15 miles east of the state line he has penetrated a hard black limestone full of beautiful white shells and lying not far above the Block Coal and lower than any other limestone known to him.

All of the above data point unmistakably to another limestone of considerable extent in the Lower Coal Measures of this region. It is shown to extend at least as far west as Alliance and in heavier body at this point than anywhere else found. So far as is known to the writer the only outcrops of this limestone occur in Mahoning County and since the best outcrop occurs at Lowellville it may be called the *Lowellville Limestone.*

CONCLUSION.

The object of this study has been to ascertain the number, the relation, the position, the continuity, and the character of these limestones below the Lower Kittanning coal in the territory outlined at the beginning of this paper. The principal facts gleaned may be set forth briefly in conclusion.

1. There are six limestone horizons below the Lower Kittanning coal in Stark and Mahoning Counties. The lowest and earliest of these is the Lowellville which was first observed by Newberry on "Grindstone Run" at Lowellville. It seems to lie just below the horizon of the Quakertown coal, and its known outcrops are limited to Mahoning County.

2. The second limestone is the Lower Mercer and was first noted by H. D. Rogers in 1858 in Mercer County, Pennsylvania. The two layer character pointed out by I. C. White, as occurring in Mercer County, is characteristic of this limestone in Mahoning County and occurs at Shew's Mill below Howenstein in Stark County. This limestone has been regarded the most persistent of the Lower Coal Measure limestones. Whatever may be said of it elsewhere, in these counties it is absent equally as often as its companion the Upper Mercer.

3. Two beds of coal occur quite generally below the Lower Mercer limestone. The upper one is usually thin and of little or no value. The lower one is of mineable thickness in places, lies 10 to 22 feet below the limestone, and is known as the Lower Mercer coal. At Shew's Mill it lies 22 feet below; 12 to 20 feet below on Little Mill Creek and Mahoning River; 10 to 17 below on Infirmary Run; and 13 below on Furnace Run.

4. The third limestone is the Upper Mercer, first recognized by Rogers on the Mahoning River and later by White in Mercer County as the Upper Mercer limestone. In Mahoning County

this limestone has the peculiarity of being interposed between two beds of coal both of which reach mineable thickness in some places. The Pennsylvania geologists have said this limestone is sparing in outcrop in Mercer County and seldom seen where the Lower Mercer is found. Had the excellent expression of this stratum in Mahoning County been seen at that time, the name Upper Mercer would quite probably never have appeared. In both counties it is sometimes absent but is present equally as often as the Lower Mercer.

Rogers states that this limestone is interposed immediately under the Tionesta sandstone (Homewood sandstone) in the vicinity of New Castle, Pennsylvania, [Geology, Pennsylvania, Vol. II, Part I, p. 489], and White in his section on the Ohio–Pennsylvania line on the Mahoning River shows the top of the Homewood sandstone to be 30 feet above the top of the Upper Mercer limestone. [U. S. Geol. Sur. Bul. 65, p. 191]. These are important points in correlating the horizons traced across the two counties with those beyond the state line. The horizons of doubtful correlation are, particularly, the Brookville coal, Clarion coal, and Putnam Hill limestone.

5. The Howenstein is the fourth limestone and is traceable across the two counties. It is last seen in full development, and without suggestion of disappearing, on Burgess Run. Its horizon is certainly marked by the coal at 1043 on Furnace Run. From White's section and the Furnace Run section the writer is unable to reach any other conclusion than that the Howenstein limestone caps the Brookville coal. The Homewood sandstone so conspicuous in Pennsylvania thins down on entering Ohio and becomes shale in the Furnace Run section but regains its massive character locally as seen at Club Lake where it is 28 feet thick, and rests upon a remnant of the Upper Mercer coal. Failing as it does it is no longer a guide to mark the top of the Pottsville formation in these counties, but the Howenstein limestone directly overlying the Brookville coal comes in to be the guide in finding the horizons.

6. The Putnam Hill, first recognized by Andrews, 1869, in Putnam Hill at Zanesville, Ohio, is the fifth limestone. It lies in rather heavy body through Stark County and in western Mahoning County. It thins out toward the east and is absent in the eastern part of the county. The last trace of it was found at the Ewing mine in southwestern Canfield Township by Dr. Orton. The coal at 1078 feet above sea in the Furnace Run section marks its horizon and appears to be the Clarion coal of western Pennsylvania. It is worthy of note that in the interval between the Brookville, and clarion coals sandstone prevails through Mahoning County and is present through central

Stark County but with less prominence. It is usually shaly or flaggy and soft, but occasionally it becomes fairly firm and massive, yet nowhere showing the massiveness of the Homewood at Club Lake.

7. The sixth and highest of these limestones is the Vanport named by Clapp in 1904 but well known previously as the Ferriferous limestone. This stratum enters Ohio at Lowellville with a thickness of 16 feet, but suddenly dies out westward. In central Mahoning County its coal thickens and becomes the well known "Canfield Cannel Coal" but without its limestone covering. In southwestern Mahoning County the Vanport reappears and is found at different points in considerable body at least as far westward as central Stark County. The outcrops of the Vanport and Putnam Hill overlap, and the two are sometimes present in the same section. This is particularly true in the vicinity of Middle Branch in Stark County where the Putnam Hill reaches its maximum development and with the Vanport above it in heavy body. Southward from this locality the Putnam Hill maintains a fairly heavy body but the Vanport again dies out at Canton and has only feeble expression in the southern part of the county.

8. All of the limestones undulate and this occasionally becomes very pronounced. Variation in the intervals between them is more often due to undulation than to a general thickening or thinning of intermediate strata.

9. The dip of the strata in the region covered is decidedly variable and a uniform dip of 15 to 20 feet per mile toward the southeast is untenable. The variation appears to be due to low folds one of which seems to extend through western Columbiana County and through central Mahoning County, and with the crest in the vicinity of the village of Canfield. A second fold is thought to extend through the western part of Stark County and with the crest to the west of Canton.

TABLE OF OUTCROPS AND ELEVATIONS.

For convenience of reference the various outcrops and places at which limestone occurs with the identification and elevation are given in tabular form. In a few instances the limestone is absent, but its horizon is clearly marked by fireclay or coal, or both.

TABLE OF LIMESTONES AND ELEVATIONS

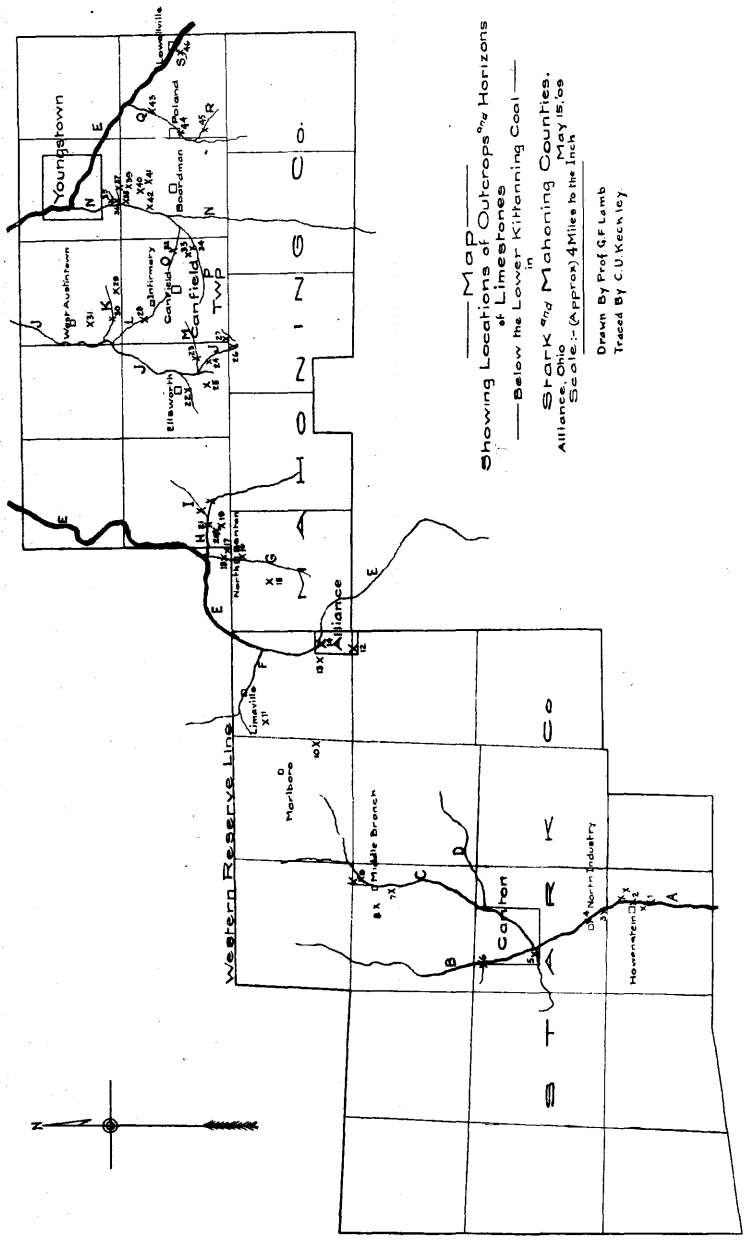
Place	Name of Limestone					
	Lowell-ville	Low. Mer.	Up. Mer.	Howen-stein	Put. Hill	Van-port
Howenstein	....	939	967	991	1051	1086
North Industry	....	....	979	....	1057	....
S. W. Canton	....	....	1003	1025	1075	....
N. W. Canton	....	....	....	....	1090	....
Worstler Outcrop	....	....	....	....	1120	....
Werner Outcrop	....	....	....	....	1130	....
Cement Plant	....	....	....	....	1143	1180
Carr Outcrop	....	....	....	....	....	1117
Ellett Outcrop	....	....	....	....	....	1081
Alliance	882	945	966	1008	1032	....
Best's Station	....	....	....	....	1084	1101
North Benton	....	1015	1043	1069	....	....
Henry Outcrop	....	....	1048	....	....	....
Hartzell Outcrop	....	....	1037	....	....	....
Pottery Plant	....	....	....	1075	....	....
Little Mill Cr	....	1015	....	....	....	....
Ellsworth	....	1023	....	....	....	....
Diehl Creek	....	1024	....	....	....	....
Lower Outcrop	....	....	1040	....	....	....
Bingham Outcrop	....	....	....	1072	....	....
Unger Outcrop	....	....	....	1082	....	....
Ewing Mine	....	....	....	....	1115	....
Beardsley Outcrop	....	1021	....	....	....	....
Ripple Outcrop	....	1028	....	....	....	....
McMahon Outcrop	....	1040	....	....	....	....
Smith Corners	....	....	....	1090	....	....
Facodi Outcrop	....	1010	....	....	....	....
Lanterman Outcrop	....	1007	....	....	....	....
Baldwin Outcrop	....	1010	1050	....	....	....
Davis Well	....	....	1050	....	....	....
Moyer Spring	....	1030	....	....	....	....
Geiger Well	910	1021	....	....	....	....
Walters Well	....	1018	....	....	....	....
Greenhouse Hill	....	....	....	1076	....	....
Indian Creek	....	....	1039	1064	1089	1139
Neff Run	....	1029	1050	1078	....	....
Yellow Cr. Gorge	884	....	....	....	....	....
Poland	....	990	1013	....	....	....
Burgess Run	....	....	....	1050	....	....
Furnace Run	912	995	1020	1043	1078	1128

KEY TO ACCOMPANYING MAP.

The streams, cities and villages, and points of outcrop or place of occurrence of limestone are fairly accurately located on the accompanying map. Those streams, towns, and outcrops mentioned in the foregoing description are for the most part, located on the map. Streams are named by letter, and points of outcrop by numbered cross.

STREAMS

A..... Nimishillen Creek
B..... West Branch Nimishillen
C.....Middle Branch Nimishillen
D.....East Branch Nimishellen
E.....Mahoning River
F..... Deer Creek
G..... Island Creek
H..... Little Mill Creek
I.....Turkey Broth Creek
J..... Meander Creek
K..... McMahon Run
L..... Infirmary Run
M..... Diehl Creek
N..... Mill Creek
O..... Neff Run
P..... Indian Creek
Q..... Yellow Creek
R.....Burgess Run
S..... Furnace Run


Map
Showing Locations of Outcrops of Horizons of Limestones
Below the Lower Kittanning Coal
in
Stark and Mahoning Counties.
Alliance Ohio (Approx) 4 Miles to the Inch.
Scale:-
May 15, 08
Drawn By Prof. G. F. Lamb
Traced By C. U. Keckley
Youngstown
Lowellville
Poland
Boardman
Canfield TWP
Sugar Austintown
Ellsworth
Alliance
Western Reserve Line
Maribore
Middle Branch
Carrollton
Homerton
North Industry
MAHONING
STARK

POINTS OF OCCURRENCE OF LIMESTONES OR THEIR HORIZONS

1. Shews' Mill Outcrop
2. Howenstein Outcrops
3. Stallman Outcrops
4. North Industry Outcrops
5. Southwest Canton Outcrops
6. Northwest Canton Outcrop
7. Worstler Outcrop
8. Werner Outcrop
9. Cement Plant Outcrops
10. Carr Outcrop
11. Lare Mine
12. Alliance Test Well No. 1
13. Ellett Outcrop
14. Alliance Test Well No. 2
15. Best's Station Outcrops
16. North Benton Outcrops
17. Henry Outcrop
18. Island Creek Mine
19. Dustman Pottery Plant
20. Hartzell Outcrop
21. Little Mill Creek Outcrops
22. Club Lake Outcrop
23. Diehl Creek Outcrop
24. Lower Outcrop
25. Bingham Outcrop
26. Unger Outcrop
27. Ewing Mine
28. Beardsley Outcrop
29. Smith Corners
30. McMahon Outcrop
31. Ripple Outcrop
32. Neff Run Outcrops
33. Swanston Mine, Cannel Coal
34. Indian Creek Outcrops
35. Facodi Outcrop
36. Lanterman Outcrop
37. Greenhouse Hill Outcrop
38. Baldwin Outcrop
39. Davis Well
40. Moyer Spring
41. Geiger Well
42. Walters Well
43. Yellow Creek Gorge Outcrop
44. Poland Outcrops
45. Burgess Run Outcrop
46. Furnace Run Outcrops

Mount Union College.